# Chapter 6
# Industry, Technology, and the Global Marketplace

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# Highlights

## Knowledge- and Technology-Intensive Industries in the World Economy

**KTI industries have been a major and growing part of the global economy, with the United States having the highest KTI share of GDP of any large economy.**

- Global value added of knowledge- and technology-intensive (KTI) industries, consisting of five knowledge-intensive (KI) service and five high-technology (HT) manufacturing industries, totaled $18.2 trillion in 2010. This represents 30% of estimated world gross domestic product (GDP) in 2010, compared with a 27% share in 1995.
- The U.S. economy had the highest concentration of KTI industries among major economies (40% of U.S. GDP). The KTI concentrations for the European Union (EU) and Japan were 32% and 30%, respectively.
- Major developing economies have lower KTI shares than developed economies. China's KTI industries created 20% of GDP in 2010 compared to 17% in 1995. The KTI shares in Brazil, India, and Russia were similar to China's.

**Rising KTI shares in most countries have coincided with growth in productivity. But productivity growth in the world's developed economies since 2000 has been slower than in developing economies.**

- Labor productivity growth in the United States and other developed countries slowed from 1.9% in the 1990s to 1.3% from 2000 to 2008, coinciding with slackening growth in their per capita GDP.
- Labor productivity growth in developing countries accelerated from 1.4% in the 1990s to 4.9% from 2000 to 2008, led by China, India, and Russia. China's labor productivity grew at a 10% annual average with its per capita GDP increasing from 8% to 20% of U.S. per capita GDP.

## Worldwide Distribution of Knowledge- and Technology-Intensive Industries

**The commercial KI service and HT manufacturing industries in the United States are collectively larger than in any other country. China's KI and HT industries have been growing rapidly, making China a major center of global activity.**

- The United States has larger output ($3.6 trillion) than any other country in commercial KI service industries (business, financial, and communications). However, the U.S. share of world output fell substantially in the last decade from 42% in 2000 to 33% in 2010.
- China's world share of commercial KI service industries rose from 2% in 1995 to 7% in 2010, led by 20% average annual growth of its communications industry.
- U.S. HT manufacturing industries have a larger share of global output than any other economy. The U.S. global share fell from 34% in 1998 to 28% in 2010.
- China's share of the world's HT manufacturing rose sixfold from 3% in 1995 to 19% in 2010, surpassing Japan in 2007. Its share grew rapidly across all HT manufacturing industries, reaching nearly 50% in computers, 26% in communications, and 17%–18% in pharmaceuticals and semiconductors.

**Global output of commercial KI services was flat and HT manufacturing declined in 2009 in the midst of the recession. Global output of commercial KI services and HT manufacturing recovered in 2010 with China and other developing economies leading the recovery.**

- Global output of commercial KI services was flat in 2009 as part of the worldwide recession. Output in developed countries declined by 1%. But output grew by 4% in developing economies, led by double-digit growth in China. Commercial KI services resumed growing in 2010, led by a 20% increase by developing countries.
- Global output of HT manufacturing industries declined by 6% in 2009. It dropped by 7% for developed economies, but was flat in developing countries, with China growing by 9%. Global output bounced back in 2010, rising 14%, propelled by China and other developing countries.

## Trade and Other Globalization Indicators

**Worldwide, commercial KTI exports have grown faster than their KTI production, indicating increased globalization in these industries.**

- The export share of commercial KI production rose from 5% in 1995 to 8% in 2010 suggesting a modest rate of globalization. Advances in information and communications technology (ICT) and emerging capabilities in both developed and developing countries, such as India, are driving globalization of commercial KI services.
- The export share of HT manufacturing production rose from 36% to 53% in 2006 before drifting downward to 50% in 2010.

**The United States is the second-largest exporter behind the EU of commercial KI services and runs a large surplus. In HT goods, the United States has lost export share and faces a widening trade deficit.**

- The United States exported $290 billion of commercial KI services (business, computer and information services, finance, and royalties and fees), with a 22% share of global exports behind the EU's 30%. The Asia-8 and China are the next two largest exporters with global shares of 15% and 8%, respectively.

- The U.S. trade surplus in commercial KI services rose from $55 billion in 2000 to reach more than $100 billion in 2009; during this same period, however, the U.S. trade deficit in HT manufacturing goods grew.
- China's and the Asia-8's surpluses in commercial KI services have grown over the last decade to reach about $30 billion in 2009. The increase in the Asia-8's surplus reflects rising surpluses in computer and information services.

**While the U.S. share of global HT exports declined, China became the world's largest exporter of HT goods.**

- The U.S. share of global HT exports rose from 19% to 22% from 1995 to 1998 before declining to 14%–15% during the period from 2003 to 2010 because of losses in communications and computers. The U.S. deficit in HT trade widened from $67 billion to $94 billion during the 2000s, driven by rising deficits in communications and computer goods.
- China's share of global HT goods exports more than tripled, from 6% in 1995 to 22% in 2010, making it the single largest exporting country for HT products. China's trade surplus in these products increased from less than $20 billion in 2002 to nearly $160 billion in 2010, largely because of rising surpluses in computer and communications goods.
- China's rise as the world's major assembler and exporter of many electronic goods is reflected in a sharp increase in China's share of imports of intermediate communications and computer goods originating from other Asian economies. Most of China's exports of electronics goods are destined for the United States, the EU, and Japan.

**A separate measure of U.S. HT trade shows patterns in U.S. HT trade similar to those found in internationally comparable trade data.**

- According to U.S. Census data on U.S. trade in advanced technology products (ATP), the United States first generated a trade deficit in ATP in 2002 that widened to $82 billion by 2010. The deficit in ICT products alone reached more than $120 billion in 2010. Aerospace and electronics generated a combined surplus of $70 billion in 2010.
- The largest U.S. trade deficit in ATP was $87 billion with China, its largest trading partner country in total goods and ATP trade, followed by $17 billion with the Asia-8, and $8 billion with Japan. ICT deficits with these Asian economies were higher, offset by lower deficits or positive trade balances in other ATP categories.

**U.S. foreign overseas investment in KTI industries exceeds foreign investment in U.S. KTI industries.**

- The stock of U.S. overseas investment in KTI industries was $1.1 trillion, and the stock of foreign direct investment in the United States in these industries was almost $700 billion.
- The bulk of U.S. overseas KTI investment was in service industries ($1 trillion), with less than 15% in HT manufacturing industries ($125 billion) in 2009.
- Financial services had by far the largest share in the stock of U.S. overseas investment in commercial KI service industries (74%), followed by business services (19%). Among HT manufacturing industries, pharmaceuticals (41%) and semiconductors (25%) had the largest shares.
- The stock of foreign direct investment (FDI) in the United States in commercial KI service industries stood at $433 billion in 2009; FDI in U.S. HT manufacturing industries stood at $222 billion.
- Financial services had the largest share (68%) in the stock of FDI in commercial KI service industries, followed by business services (19%) and communications (13%). Pharmaceuticals accounted for 68% of the share for HT manufacturing industries.

## Innovation-Related Indicators of the United States and Other Major Economies

**U.S. firms in commercial KTI industries reported much higher incidences of innovation than other industries.**

- Four HT manufacturing industries—computers, communications, scientific and measuring instruments, and pharmaceuticals—reported rates of product and process innovation that were at least double the U.S. manufacturing sector average.
- In the U.S. nonmanufacturing sector, software firms lead, with 77% of companies reporting the introduction of a new product or service compared to the 7% average for all nonmanufacturing companies. Innovation is also two to three times higher than the nonmanufacturing average in telecommunications/Internet industries.

**The U.S. share of patents granted by the U.S. Patent and Trademark Office has declined over the last decade, which may indicate increased technological capacity abroad.**

- The U.S. resident share of U.S. Patent and Trademark Office (USPTO) patents granted has gradually fallen since the late 1990s, from 54% in 1998 to 52% in 2002 and down to 49% in 2010. The EU, Japan, and the Asia-8 were the main recipients of USPTO patents granted to non-U.S. countries, with a collective share of nearly 90%.
- The United States has a higher concentration relative to other major economies in USPTO patenting activity in several advanced and science-based technologies, including ICT, automation, biotechnology, and pharmaceuticals.
- The United States has a similar share to the EU and Japan in patents sought in three of the world's largest markets—the United States, the EU, and Japan. The United States, the EU, and Japan have similar shares of these high-value patents, accounting for nearly 90% of the total.
- U.S. microbusinesses (those with fewer than five employees) in industries classified as HT by the Bureau of Labor Statistics (BLS) grew much faster than in other industries

during the period 2000–08. Growth of microfirms in services classified as HT was three times that of other service industries.

- The three HT services with the largest number of microbusinesses are management, scientific, and technical consulting; computer systems design; and architectural and engineering. HT manufacturing industries with large number of microfirms include navigational, measuring, and electromedical equipment and semiconductors.

## Investment and Innovation in Clean Energy and Technologies

**According to commercial investment data from Bloomberg, China in 2010 provided more investment in clean energy and technologies than any other country.**

- Chinese commercial investment in clean energy and technologies, which Bloomberg defines to include wind, solar, biofuels, and energy efficiency, rose exponentially from less than $1 billion in 2004 to $53 billion in 2010. The bulk of China's investment was in wind energy ($45 billion).
- The United States and the EU each provided about $30 billion in clean energy finance in 2010. Wind energy accounts for the largest share (60%) of U.S. investment, with solar the second largest.

**The United States is the leading investor of venture capital in clean energy and technologies.**

- Worldwide venture capital investment in clean energy and technologies rose rapidly, more than quadrupling from $1 billion to $4 billion from 2004 to 2010. The United States is the largest source of this type of investment, providing more than 80% of global energy-related venture capital.
- Two technologies, energy smart/efficiency and solar, dominate venture capital investment. Each has a 40% share.

**According to data from the International Energy Administration (IEA), the United States in 2009 invested more in public research, development, and demonstration for clean energy and technologies than other countries/regions.**

- Global public research, development, and demonstration (RD&D) investment for clean energy and related technologies was an estimated $17 billion in 2009. IEA data cover renewable energy, nuclear, fuel cells, carbon capture and storage, and energy efficiency.
- U.S. public RD&D investment in clean energy and technologies jumped from $2.8 billion in 2008 to $7.0 billion in 2009. However, this increase reflected one-time stimulus funding under the American Recovery and Reinvestment Act (ARRA). In 2010, U.S. public RD&D fell to $4.4 billion, when ARRA funding declined.
- The EU and Japan each funded about $4 billion in 2009, equivalent to a 24% global share.

# Introduction

## Chapter Overview

Policymakers in many countries increasingly emphasize the central role of knowledge, particularly R&D and other activities that advance science and technology, in a country's economic growth and competitiveness. This chapter examines the downstream effects of these activities on the economies of the United States and its major competitors in the global marketplace.

Knowledge- and technology-intensive (KTI) industries in both the service and manufacturing sectors are a major focus of the chapter. These industries are considered to have a particularly strong link to science and technology. In many cases, these industries develop technological infrastructure that diffuses across the entire economy. Information and communications technology (ICT), for example, is widely regarded as a transformative "platform" technology that has altered lifestyles and the conduct of business across a wide range of sectors. Industries that are less knowledge and technology intensive, however, remain very important in the world economy and therefore receive some attention in the chapter.

The globalization of the world economy involves the rise of new centers of KTI industries. Although the United States continues to be a leader in these industries, developing economies, especially in Asia, have vigorously pursued national innovation policies in an effort to become major producers and exporters of KTI goods and services. Advances in science and technology have enabled companies to spread KTI activity to more locations around the globe while also maintaining strong interconnections among geographically distant entities.

Innovation is closely associated with technologically led economic growth, and observers regard it as important for advancing living standards. The measurement of innovation is an emerging field, and current data and indicators are limited. However, activities related to the commercialization of inventions and new technologies are regarded as important components of innovation indicators. Such activities include patenting, the creation and financing of new high-technology (HT) firms, and investment in intangible goods and services.

In recent years, innovations aimed at developing improved technologies for generating clean and affordable energy have become increasingly important in both developed and developing countries. Clean energy has a strong link to science and technology. Like ICT, energy is a key element of infrastructure, the availability of which can strongly affect prospects for growth and development. For these reasons, the chapter pays special attention to energy technologies.

## Chapter Organization

This chapter is organized into five sections. The first section discusses the increasingly prominent role of KTI industries in regional/national economies around the world. The focus is on the United States, the European Union (EU), Japan, China, and the Asia-8—India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand—which are included because of their substantial activity in KTI production and trade and growing trade ties with China. The timespan is from the early 1990s, roughly the end of the Cold War, to the present.

The second section describes the global spread of KTI industries and analyzes regional and national shares of worldwide production. It discusses shares for the KTI industry groups as a whole and for particular services and manufacturing industries within them. Because technology is increasingly essential for non-HT industries, some data on the latter are presented as well.

The third section examines indicators of increased interconnection of KTI industries in the global economy. Data on patterns and trends in global trade in KTI industries make up the bulk of this section. It presents bilateral trade data to provide a rough indication of the internationalization of the supply chains of HT manufacturing industries, with a special focus on Asia. The section also presents data on U.S. trade in advanced technology products, examining trends in U.S. trade with major economies and in key technologies. Domestic and foreign production and employment of U.S. multinationals in KTI industries are presented as indicators of the increasing involvement of these economically important firms in cross-border activities. To further illustrate the effects of globalization on the United States, the section presents data on U.S. and foreign direct investment abroad, showing trends by region and by KTI industries.

The fourth section presents innovation-related indicators. Using a new classification system, it examines country shares in patents granted by the United States in various technologies. It next examines patterns in country shares of high-value patents. It presents innovation-related data on U.S. industries from the National Science Foundation's new Business R&D and Innovation Survey. A discussion of U.S. HT small businesses includes data on the number of HT small business startups and existing firms, employment, and venture and angel capital investment by industry.

The last section presents data on clean energy and energy conservation and related technologies, which have become a policy focus in developed and developing nations. They are knowledge and technology intensive and thus are closely linked to scientific research and development. Production, investment, and innovation in these energies and technologies are rapidly growing in the United States and other major economies.

## Data Sources, Definitions, and Methodology

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems. The sidebar, "Comparison of Data Classification Systems Used," shows the classification systems used in this chapter.

## Comparison of Data Classification Systems Used

| Topic | Data provider | Variables | Basis of classification | Coverage | Methodology |
|---|---|---|---|---|---|
| Knowledge-intensive (KI) service and high-technology (HT) manufacturing industries | IHS Global Insight, World Industry Service database (proprietary) | Production, value added | Industry basis using International Standard Industrial Classification (ISIC) | KI services—business, financial, communications, health, and education services<br>HT manufacturing—aircraft and spacecraft, pharmaceuticals, office and computer equipment, communications, and scientific and measuring equipment | Uses data from national statistical offices in developed countries and some developing countries, and estimates by IHS for some developing countries |
| Trade in commercial KI services (new for 2012) | World Trade Organization | Exports and imports | Product basis using Extended Balance of Payments Services Classification | KI services—business, financial, communications, and royalties and fees | Uses data from national statistical offices, International Monetary Fund, and other sources |
| Trade in HT goods | IHS Global Insight, World Trade Service database (proprietary) | Exports and imports | Product basis using Standard International Trade Classification (SITC) | Aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific and measuring instruments | Uses data from national statistical offices and estimates by IHS Global Insight |
| U.S. trade in advanced-technology products | U.S. Census Bureau | Exports and imports | Product basis using Harmonized Commodity Description and Coding System, 10 technology areas classified by U.S. Census | Advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications, life science, nuclear technology, optoelectronics, and weapons | Data collected from automated reporting by U.S. customs |
| Globalization of U.S. multinationals | U.S. Bureau of Economic Analysis (BEA) | Value added, employment, and inward and outward direct investment | Industry basis using North American Industrial Classification System (NAICS) | Commercial KI services—business, financial, communications<br>HT manufacturing—aerospace, pharmaceuticals, office and computer equipment, communications, and scientific and measuring equipment | BEA annual surveys of U.S. multinationals and U.S. subsidiaries of non-U.S. multinationals |
| U.S. industry innovation activities | NSF, Business R&D and Innovation Survey | Innovation activities | U.S. businesses with more than five employees | Industries classified on industry basis using NAICS | Survey of U.S. located businesses with more than five employees using nationally representative sample |

*Continued on following page*

### Comparison of Data Classification Systems Used—continued

| | | | | | |
|---|---|---|---|---|---|
| U.S. Patent and Trademark Office (USPTO) patents | The Patent Board | Patent grants | Inventor country of origin, technology area as classified by the Patent Board | More than 400 U.S. patent classes, inventors classified according to country of origin and technology codes assigned to grant | Source of data is USPTO |
| Triadic patent families | Organization for Economic Co-operation and Development (OECD) | Patent applications | Inventor country of origin and selected technology area as classified by OECD | Broad technology areas as defined by OECD, inventors classified according to country of origin | Sources of data are USPTO, European Patent Office, and Japanese Patent Office |
| U.S. trademarks (new for 2012) | USPTO | Trademark applications | Applicant country of origin, trademark class as determined by USPTO | 45 trademark goods/services classes; trademarks, applicants classified by country of origin | Source of data is USPTO |
| Venture capital | Dow Jones Venture source (new for 2012) | Investment, technology area, country of investor origin | Technology areas as classified by Dow Jones classification system | 27 technology areas, investment classified by venture firms' country of location | Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals |

## Knowledge- and Technology-Intensive Industries in the World Economy

Science and technology are widely regarded as important for the growth and competitiveness of individual industries and for overall national economic growth. Indeed, global economic growth increasingly depends on science, technology, and other knowledge-based assets. Policymakers in developed and developing countries are striving to attract, cultivate, and retain knowledge-based companies and workers to foster national prosperity and to increase national access to the global economy.[1]

The Organisation for Economic Co-operation and Development (OECD 2001, 2007) has identified 10 categories of industries that have a particularly strong link to science and technology.[2] Data on worldwide production in these industries can be used to examine their growing importance in the United States and other major economies.[3] These industries include both knowledge-intensive (KI) service industries and industries that produce high-technology (HT) manufactured goods. Collectively referred to as knowledge- and technology-intensive (KTI) industries, they include:

- Five KI service industries that incorporate HT either in their services or in the delivery of their services. Three of these—financial, business, and communications services (including computer software and R&D)—are generally commercially traded. The others—education and health services—are publicly regulated or provided and remain relatively more location bound.
- Five HT manufacturing industries that spend a large proportion of their revenues on R&D and make products that contain or embody technologies developed from R&D. These are aircraft and spacecraft, pharmaceuticals, computers and office machinery, semiconductors and communications equipment (treated separately in the text), and scientific (medical, precision, and optical) instruments.[4] Trends in aircraft and spacecraft and pharmaceuticals are particularly sensitive to government policies. Aircraft and spacecraft trends are affected by funding for military aircraft, missiles, and spacecraft and by different national flight regulations. National regulations covering drug approval, prices, patent protection, and importation of foreign pharmaceuticals can affect pharmaceuticals.

This report gives special attention to KTI industries in information and communications technology (ICT). ICT combines the HT manufacturing industries of computers and office machinery, communications equipment, and semiconductors with the KI services of communications and computer programming (a subset of business services). ICT industries are important because they provide the infrastructure for many social and economic activities, facilitating innovation and economic growth.[5]

This section examines the role of KTI industries in the global economy. (For a discussion of value added and other measures of economic activity, see sidebar, "Industry and Trade Data and Terminology"). For context, selected data are presented on wealth, productivity growth, and ICT infrastructure of selected economies, with a focus on the United States and other economies in which KTI industries play a particularly large or rapidly growing role.

## Industry and Trade Data and Terminology

The data and indicators reported here permit the tracing and analysis of broad patterns and trends that shed light on the broadening and shifting distribution of global knowledge- and technology-intensive capabilities. The industry-level production and trade data used in this chapter derive from a proprietary IHS Global Insight database that assembles data from the United Nations and the Organisation for Economic Co-operation and Development to cover 70 countries in a consistent way. IHS estimates some missing data for some of the developing countries.

Two measures of industry activity—value added and trade volume—are expressed in current dollars. Value added is the amount contributed by an economic entity—country, industry, or firm—to the value of a good or service. It excludes purchases of domestic and imported supplies as well as inputs from other countries, industries, or firms.

Value added is an imperfect measure. It is credited to countries or regions based on the reported location of the activity, but globalization and the fragmentation of supply chains mean that the precise location of an activity is often uncertain. Companies use different reporting and accounting conventions for crediting and allocating production performed by their subsidiaries or companies in foreign countries. Moreover, the value added of a company's activity is assigned to a single industry based on the largest share of the company's business. However, a company classified as manufacturing may include services, and a company classified in a service industry may include manufacturing or may directly serve a manufacturing company. Thus, value-added trends should be interpreted as broad and relatively internally consistent indicators of the changing distribution of where economic value is generated.

Data on exports and imports represent the market value of products in international trade. This measure is not comparable with the value-added measure of industry production. Exports and imports are credited to the country where the product was "substantially transformed" into final form, but for exports produced in multiple economies, the assigned country may not be the location with the highest value added.

## Growth of Knowledge- and Technology-Intensive Industries in the World and Major Economies

KTI industries have become a major part of the global economy and represent a growing share of many countries' total economic activity. Global value added of these industries totaled $18.2 trillion in 2010 (figure 6-1 and appendix table 6-1). This represents 30% of estimated world gross domestic product (GDP), compared with a 27% share of a much smaller global economy 15 years earlier (figure 6-2 and appendix table 6-2). Almost all of the share increase occurred between 1995 and 2001. Most of the increase in the KTI share of the world economy stemmed from growth in KTI industries in the United States, the European Union (EU), Japan, and several developing economies.

The KTI shares of the total economic output of the United States, EU, and Japan rose by 4–7 percentage points from 1995 to 2010, reaching 40% in the United States, 32% in the EU, and 30% in Japan (figure 6-3). The higher U.S. share relative to the EU and Japan reflects a greater intensity of commercial KI services, notably finance and business services. The KTI share increases in the economies of South Korea and Taiwan were larger, rising by 7–10 percentage points to 29% and 32%, respectively, with increases occurring in both manufacturing and service industries. South Korea and Taiwan both became wealthy, developed economies during this period.

KTI shares also grew in most of the developing economies. China's KTI share grew by 3 percentage points to reach 20%, driven by a doubling of HT manufacturing share and increases in commercial KI services and education (figure 6-3). In India and Russia, the KTI shares each rose 2–4 percentage points to reach 19% and 20% of GDP, respectively, driven by the increases in commercial and public KI service shares.

### *Commercial Knowledge-Intensive Services*

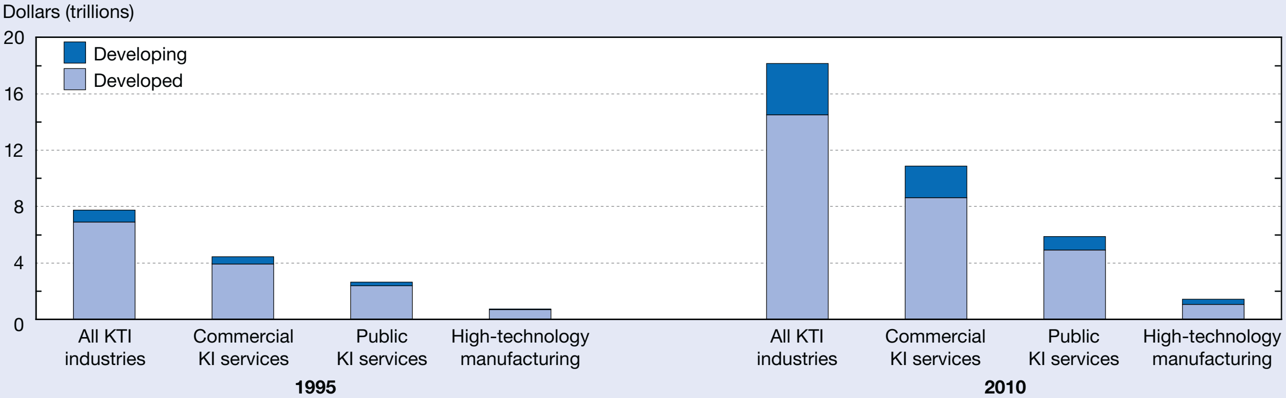
Value added of commercial KI services more than doubled from $4.4 trillion in 1995 to $10.9 trillion in 2010, representing 60% of the value added of all KTI industries ($18.2 trillion) (figure 6-1 and appendix table 6-3). In the 15 years leading up to 2010, commercial KI services increased their share of world economic activity from 15% to 18% (appendix table 6-2). Public KI services, especially education, also increased their share of the growing global GDP (figure 6-2 and appendix tables 6-4 and 6-5).

In the United States, value added of commercial KI services increased from 20% to 25% of GDP, the highest share of any large economy (figure 6-3 and appendix table 6-3). For the EU, the comparable figure rose by 4 percentage points to reach 18%, with France and Germany near the EU average and the UK above it. Japan's share rose from 15% to 17%.

The trend in large developing economies varied, with the shares of China and Brazil remaining roughly steady at 12%–14% (figure 6-3 and appendix tables 6-2 and 6-3). India's and Russia's shares each climbed by 3 percentage points to reach 13% and 14%, respectively. The differences among these economies reflect their stage of development and government policies, and may also reflect differences in the difficulty in measuring economic activity of service industries.

Commercial KI services as a percentage of non-government services (i.e., including health, education, and all commercial services) also increased (figure 6-4), and national

Figure 6-1
**Global value added of knowledge- and technology-intensive industries for developed and developing countries: 1995 and 2010**




KI = knowledge-intensive; KTI = knowledge- and technology-intensive

NOTES: Output of knowledge- and technology-intensive industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge- and technology-intensive industries include knowledge-intensive services and high-technology manufacturing industries classified by the Organisation for Economic Co-operation and Development. Knowledge-intensive services include business, financial, communications, education, and health. Commercial knowledge-intensive services include business, financial, and communications services. Public knowledge-intensive services include education and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-1, 6-3, 6-4, 6-5, and 6-11.

*Science and Engineering Indicators 2012*

differences in rates of increase were generally, but not always, similar to those for commercial KI services alone.

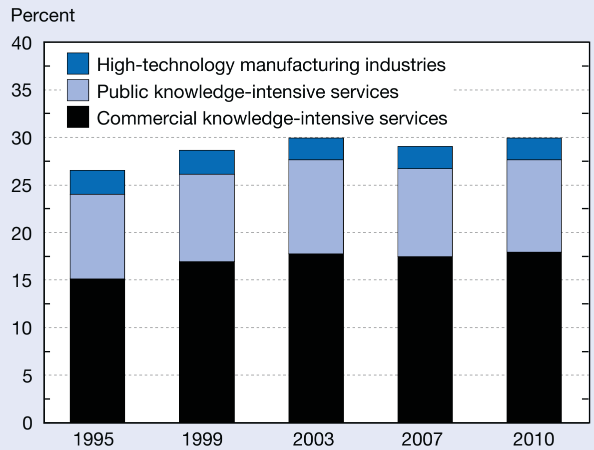
The three commercial KI service industries contributed uneven value-added amounts. The largest, business services, provided $5.7 trillion (52% of global total value added in 2010) (appendix table 6-6). Business services include the S&T intensive R&D services and computer programming industries (appendix tables 6-7 and 6-8). The second-largest, finance, provided $3.9 trillion (36% of global value added) (appendix table 6-9). Communications, crucial for information and data transactions in today's knowledge-based economies, provided $1.3 trillion (12% of global value added) (appendix table 6-10).[6]

### *Education and Health Services*

The education and health sectors generated an estimated global value added of $2.6 and $3.3 trillion, respectively, in 2010 (table 6-1 and appendix tables 6-4 and 6-5).[7] International comparison of these two sectors is complicated by variations in market structure, the size and distribution of each country's population, and the degree of government involvement and regulation. As a result, differences in market-generated value added may not accurately reflect differences in the relative value of these services.

Between 2000 and 2010, the value added generated by education services in developed countries nearly doubled, rising from $1.1 trillion to $2.0 trillion (appendix table 6-4). Output in the developing world tripled, increasing from $190 billion to $600 billion. China's output more than quadrupled, and Brazil's output nearly tripled. Russia's and India's outputs, starting from a low base, expanded more than fivefold

Figure 6-2
**Output of knowledge- and technology-intensive industries as share of GDP: 1995–2010**




GDP = gross domestic product

NOTES: Output of knowledge- and technology-intensive industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge- and technology-intensive industries include knowledge-intensive services and high-technology manufacturing industries classified by the Organisation for Economic Co-operation and Development. Knowledge-intensive services include business, financial, communications, education, and health. Commercial knowledge-intensive services include business, financial, and communications services. Public knowledge-intensive services include education and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-1, 6-2, 6-4, 6-5, and 6-11.

*Science and Engineering Indicators 2012*

Table 6-1
**Global value added of health and education services, by selected region/country/economy: 1995, 2000, 2005, and 2010**

| Characteristic | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|
| Education | | | | |
| World ($ billions) | 1,209.9 | 1,329.9 | 1,882.8 | 2,552.8 |
| United States | 30.5 | 36.3 | 33.9 | 31.6 |
| EU | 34.1 | 28.5 | 33.3 | 29.9 |
| Japan | 15.9 | 12.8 | 8.4 | 6.9 |
| China | 1.7 | 3.1 | 4.0 | 6.7 |
| Asia-8 | 4.3 | 4.7 | 5.4 | 6.2 |
| ROW | 13.5 | 14.6 | 15.0 | 18.7 |
| Health and social services | | | | |
| World ($ billions) | 1,394.7 | 1,553.6 | 2,370.3 | 3,334.9 |
| United States | 33.3 | 38.1 | 35.2 | 33.3 |
| EU | 37.3 | 31.0 | 36.0 | 33.9 |
| Japan | 13.8 | 14.1 | 11.0 | 10.3 |
| China | 1.1 | 1.7 | 1.9 | 2.8 |
| Asia-8 | 2.5 | 3.1 | 3.4 | 4.4 |
| ROW | 12.0 | 11.9 | 12.5 | 15.3 |

EU = European Union; ROW = rest of world

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-4 and 6-5.

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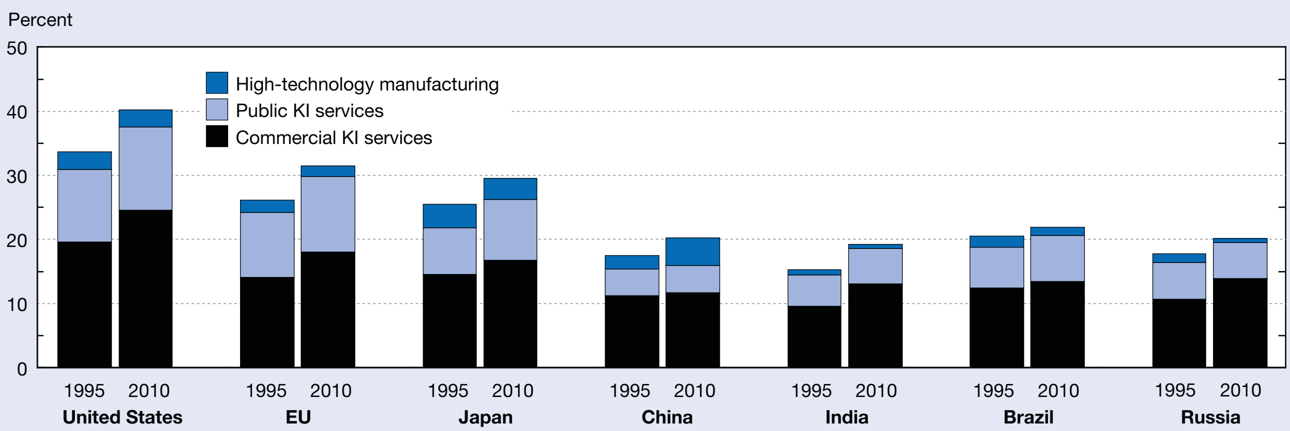
and threefold, respectively (table 6-1). Increases by these large developing economies coincided with the rapid expansion of university enrollments and graduation of new degree holders. (See "Global Trends in Higher Education in S&E" in chapter 2 for a discussion of international trends in S&E higher education.)

As with education services, production of health care services in developed countries also doubled from 2000 to 2010, rising from $1.4 trillion to $2.9 trillion (appendix table 6-5). The United States and the EU have the largest health care sectors, as measured by share of global value added (34% each) (table 6-1). The growth trend in health care for these two developed economies was similar to that in education.

### *High Technology Manufacturing*

The global value-added output of HT manufacturing industries increased from about $700 billion in 1995 to $1.4 trillion in 2010 (appendix table 6-11). However, the share of HT manufacturing industries in the global economy remained broadly steady during this period (figure 6-2 and appendix table 6-2) because of stronger overall growth in service industries than in manufacturing. In most nations, the HT manufacturing share of the economy remained flat or declined somewhat (figure 6-3). China was an exception. The HT manufacturing share of its economy doubled from 2% to 4%. This likely reflects a shift of final assembly of these goods from other Asian economies and developed economies to China.

Figure 6-3
**Output of knowledge- and technology-intensive industries as a share of GDP, by selected region/country: 1995 and 2010**




EU = European Union; GDP = gross domestic product; KI = knowledge-intensive

NOTES: Output of knowledge- and technology-intensive industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge- and technology-intensive industries include knowledge-intensive services and high-technology manufacturing industries classified by the Organisation for Economic Co-operation and Development. Knowledge-intensive services include business, financial, communications, education, and health. Commercial knowledge-intensive services include business, financial, and communications services. Public knowledge-intensive services include education and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-2, 6-3, 6-4, 6-5, and 6-11.

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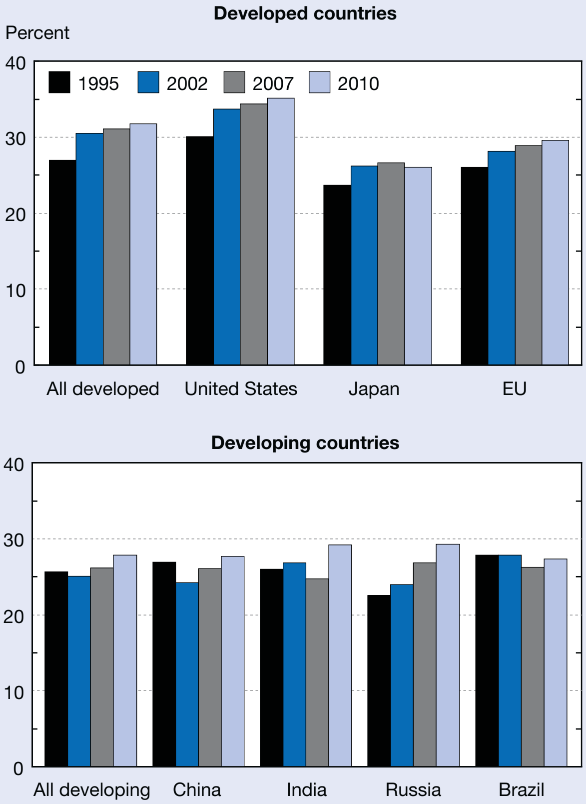
Figure 6-4
**Commercial KI service share of nongovernment services, by selected region/country: Selected years, 1995–2009**




EU = European Union; KI = knowledge-intensive

NOTES: Output of commercial knowledge-intensive and nongovernment service industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Commercial knowledge-intensive services are classified by the Organisation for Economic Co-operation and Development and include business, financial, and communications services. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011).

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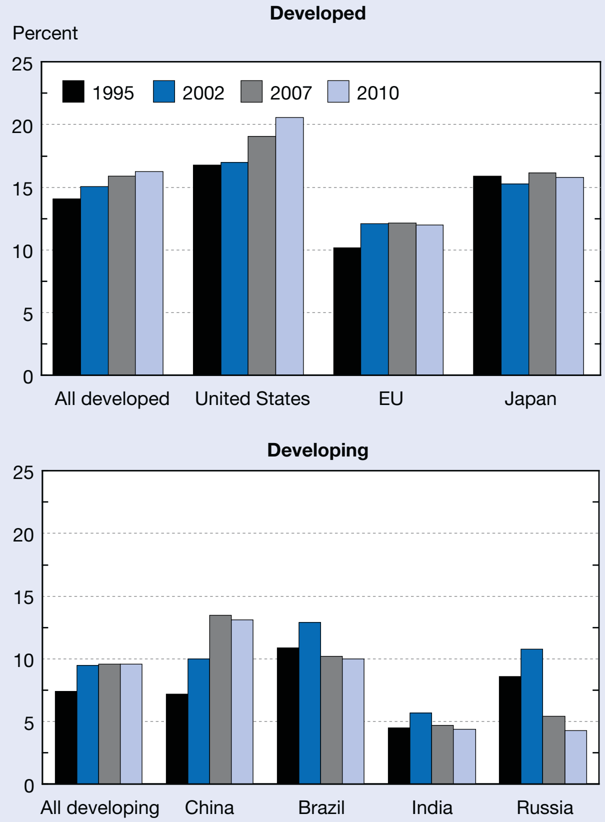
Figure 6-5
**High-technology share of manufacturing sector for selected regions/countries: 1995–2010**




EU = European Union

NOTES: Output of manufacturing industries on a value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. High-technology manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-11 and 6-12.

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Within the manufacturing sector, many economies experienced a modest shift toward HT industries. In both developed and developing economies, the HT share of the manufacturing sector has increased by 2 percentage points since 1995, reaching 16% and 10%, respectively (figure 6-5 and appendix tables 6-11 and 6-12). The HT share of the U.S. manufacturing sector, at 21% in 2010, is larger than in either the EU or in Japan. In China, the HT share increased from 7% to 13% of its total manufacturing base, similar to the proportion in the EU. However, other large developing countries underwent almost no change on this indicator.

### *Information and Communications Technology Industries*

Many economists regard information and communications technology (ICT) as a general-purpose platform technology that fundamentally changes how and where economic activity is carried out in today's knowledge based economies, much as earlier general-purpose technologies (e.g., the steam engine, automatic machinery) propelled growth during the Industrial Revolution.[8] Thus ICT facilitates broad development of new markets (e.g., for mobile computing, data exchange, and communications). Because of the shift to knowledge-based production, ICT infrastructure can be as important as or more important than physical infrastructure to raising living standards and remaining economically competitive.

The OECD has identified four ICT industries: two are manufacturing industries—semiconductors and communications equipment and computers—and two are service industries—communications and computer programming and data processing.

Value added of ICT industries more than doubled from $1.2 trillion in 1995 to $2.8 trillion in 2010 (appendix table 6-13). In 2010, developed countries generated a collective $1.9 trillion in value added, with $1.7 trillion generated by the United States, the EU, and Japan. The ICT share of the global economy, and of most major economies, showed little change between 1995 and 2010 (increasing from a 4% to a 6% share of GDP) (appendix table 6-2). In contrast, the ICT share of the Chinese economy doubled from 3% to 6%, driven by its huge expansion in ICT goods produced for export and rapid growth of its communications services.

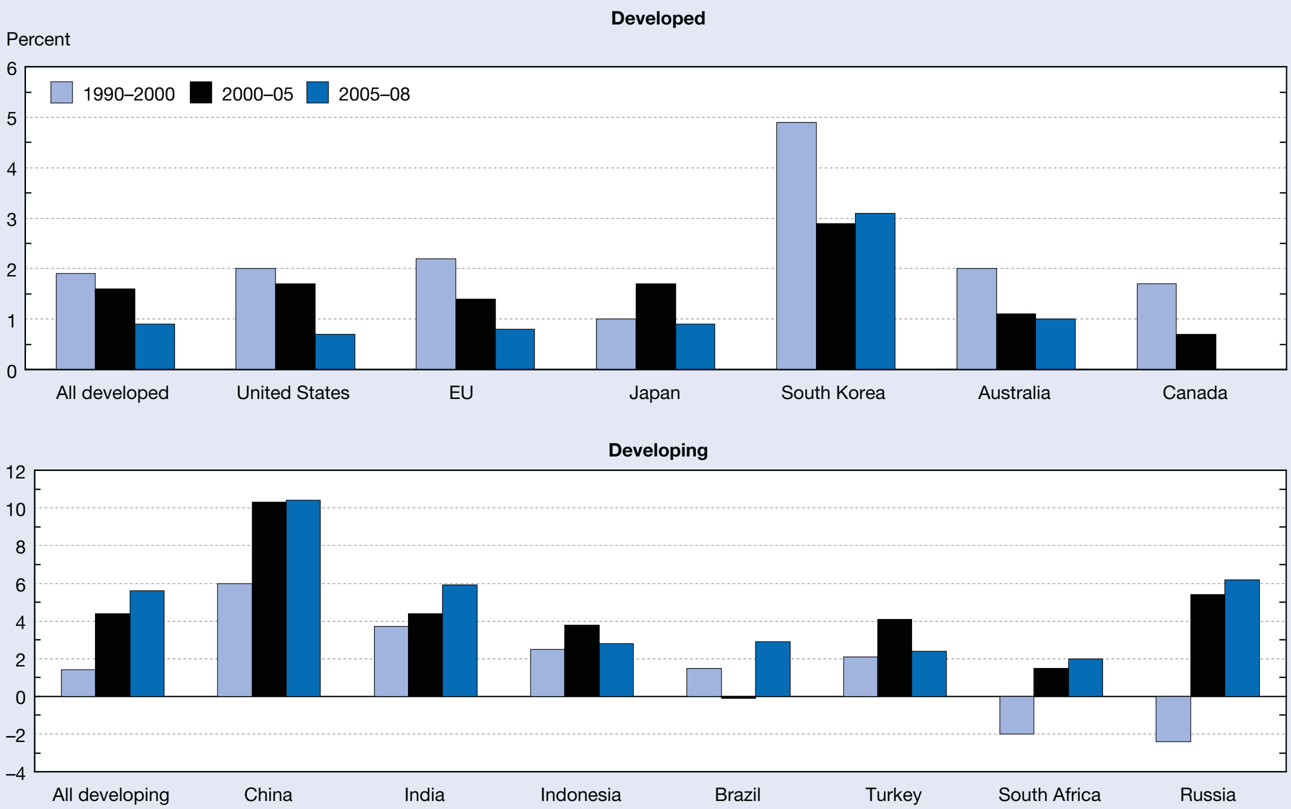
## Productivity

Productivity growth is considered essential for maintaining or advancing living standards. The growth and rise in the concentration of KTI industries in the United States, the EU, Japan, and many developing economies coincided with elevated or rapidly rising productivity. The most accurate measure of productivity—output per hour—is unavailable for many emerging economies. GDP per employed person is the proxy measure used here, spanning 1990 to 2008.

Labor productivity growth of developed economies slowed from 1.9% in the 1990s to 1.6% from 2000 to 2005 and dropped to 0.9% from 2005 to 2008 (figure 6-6 and appendix table 6-14). Growth trends in the United States and the EU were very similar to the developed world average. After lagging behind the United States and the EU in the 1990s, Japan's growth accelerated to reach the rate of the United States and the EU in the 2000s. South Korea's productivity slowed but continued to grow twice as fast (3%) as most of the large developed economies.

The growth in labor productivity in developing economies accelerated from 1.4% in the 1990s to 4.4% from 2000 to 2005 and to 5.6% for 2005–08 (figure 6-6 and appendix table 6-14). China drove this increase; its labor productivity registered the fastest growth of any large economy, from 6% in the 1990s to more than 10% for both periods in the 2000s.

Figure 6-6
**Growth in GDP per employed person for selected regions/countries: 1990–2008**




EU = European Union; GDP = gross domestic product; PPP = purchasing power parity

NOTES: GDP is in 2010 PPP dollars. EU includes current member countries. China includes Hong Kong. Brazil's growth in 2000–05 was –0.1%.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (November 2010), http://www.conference-board.org/data/productivity.cfm, accessed 15 November 2010. See appendix table 6-14.

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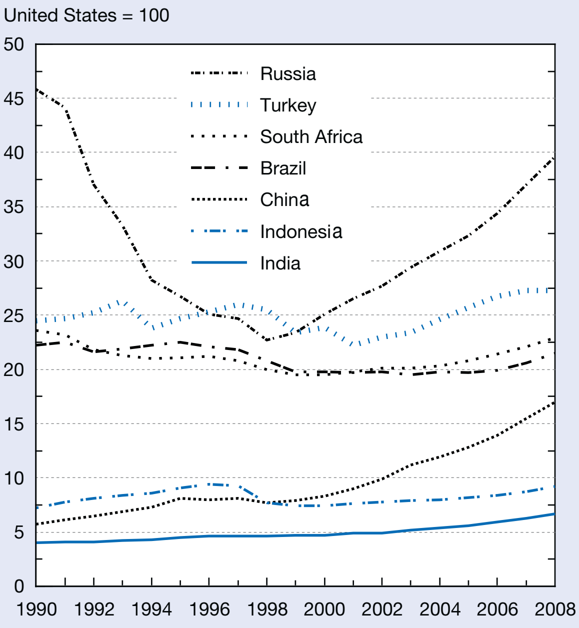
Russia's labor productivity moved from negative growth in the 1990s to a 5.4% growth rate from 2000 to 2005 and further increased to a 6.2% growth rate from 2005 to 2008. India's growth in labor productivity advanced from 3.7% to 4.4% to 5.9% over these three periods. Brazil's labor productivity grew much more slowly for much of the 2000s than the other three large developing economies, but its growth accelerated from –0.1% from 2000 to 2005 to nearly 3% from 2005 to 2008.

Rapidly rising living standards, expressed as per capita GDP, accompanied the acceleration of productivity growth in developing economies and narrowed their gap with developed countries (figure 6-7 and appendix table 6-15). Despite sustained rapid productivity growth by China and several other emerging economies, however, their gap with the United States and other developed economies is substantial and is likely to remain so for some time even if their high growth is sustained. Per capita GDP in China and Brazil remains at less than a fifth of that in the United States and in Russia at less than half. India's and Indonesia's per capita GDP remains at less than 10% of that in the United States.

Figure 6-7
**GDP per capita for selected developing economies: 1990–2008**




GDP = gross domestic product; PPP = purchasing power parity

NOTES: GDP is in 2010 PPP dollars. China includes Hong Kong.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (November 2010), http://www.conference-board.org/data/productivity.cfm, accessed 15 November 2010.

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## Information and Communications Technology Infrastructure

This section examines three broad ICT indicators: the percentage of households with broadband access; the ICT share of total fixed capital investment; and indexes of business, consumer, and government ICT infrastructure.[9] For developing economies, only the ICT infrastructure indexes are available.

The U.S. ICT infrastructure compares favorably in these three indicators to other large developed economies. South Korea is the leading country in fixed broadband penetration, with nearly 100% of its households having broadband access (figure 6-8). The United States is in the next group with household penetration of about 60% along with Australia, Canada, and Germany. The United States exceeds the EU average, France, and Japan in broadband penetration.

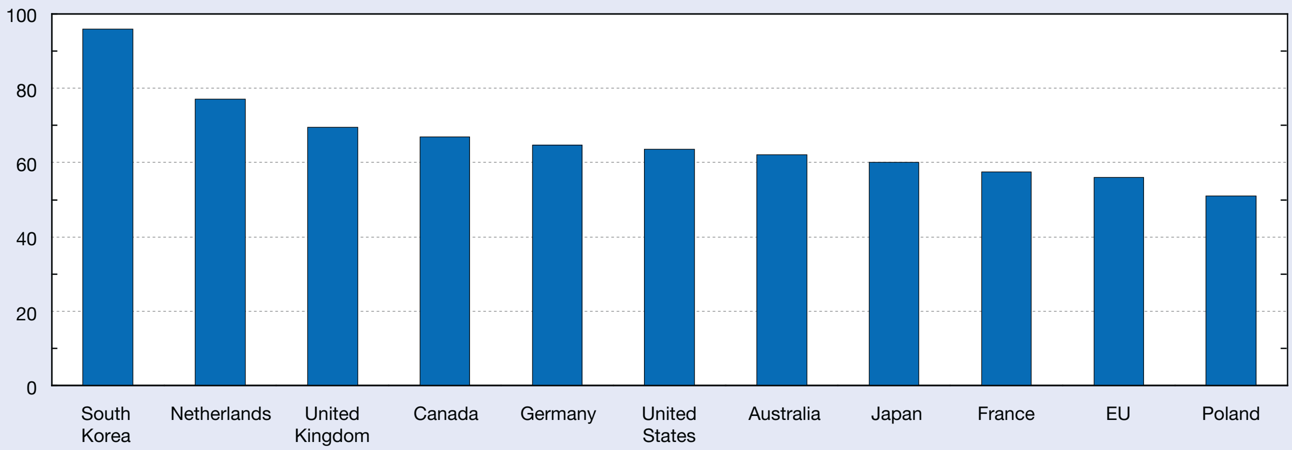
The United States has the highest ICT share of fixed capital investment (26%) of large OECD economies, with the United Kingdom a close second (figure 6-9). Five countries, Australia, Canada, Japan, France, and Germany, have shares of 13%–15%. In all of these countries, the ICT investment share has declined by large percentages since 2000; this most likely reflects rapidly falling prices of semiconductors, computers, and other ICT goods.

The United States is the leader in ICT business infrastructure among the larger developed economies (table 6-2), with an index score substantially higher than those of France, Germany, the United Kingdom, Japan, and South Korea. The United States scores near the top in ICT government infrastructure and about the same as France, Germany, the United Kingdom, Australia, and Canada in consumer infrastructure. South Korea and Japan have significantly higher scores in consumer infrastructure than the other developed economies, reflecting their lead in deployment of 3G connectivity and advanced mass-market broadband over other developed economies.

Employment data reinforce the close connection between ICT infrastructure and KTI industrial activity generally. In the United States, for example, commercial KI service industries employed about 16 million workers in 2009, or 1 of every 7 workers in the private sector, and they had a higher share of highly skilled workers than other service industries. Four commercial KI services—finance; scientific, technical, and professional services; telecommunications; and data processing hosting—have twice as high a share of workers with ICT skills compared to all service industries (figure 6-10).

Separate ICT infrastructure indexes for developing economies show wide variation among Brazil, China, India, and Russia (table 6-2). China scores third among these four economies in business infrastructure and second in consumer and government infrastructure. China's relatively weak score in ICT business infrastructure reflects very low penetration of secure Internet servers and limited international Internet bandwidth. India scores the lowest among the four in the three indexes, reflecting factors such as limited

Figure 6-8
**Household broadband penetration, by selected region/country: 2009**




EU = European Union

NOTE: EU includes current member countries.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Directorate for Science Technology and Industry, OECD Broadband Portal, http://www.oecd.org/document/54/0,3746,en_2649_33703_38690102_1_1_1_1,00.html, accessed 15 February 2011.

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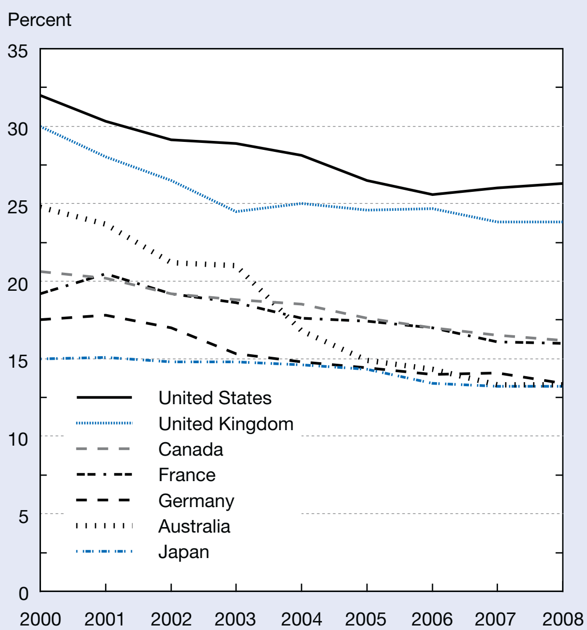
Figure 6-9
**ICT share of fixed capital investment for selected countries: 2000–08**




ICT = information and communications technology

SOURCE: Organisation for Economic Co-operation and Development, Statistics Portal, Productivity, http://www.oecd.org/topicstatsportal/0,3398,en_2825_30453906_1_1_1_1_1,00.html, accessed 15 February 2011.

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availability of public telephone lines, modest Internet usage and subscriber levels, and very low penetration of secure Internet servers.

Of the four large developing economies, Brazil ties with Russia as having the highest score in business infrastructure and with China for second in consumer infrastructure (table 6-2). Brazil's score in business infrastructure reflects higher penetration rates of secure Internet servers and personal computers. Brazil has the highest score in ICT government infrastructure.

Among the four large developing economies, Russia leads in consumer infrastructure, ties with Brazil in business infrastructure, and scores roughly the same as China in government infrastructure. Russia's relatively high score in consumer infrastructure reflects its levels of fixed and mobile telephone penetration and strong Internet and broadband subscription levels. Russia's business infrastructure score reflects a relatively high penetration of personal computers and telephones offset by low penetration of secure Internet servers and limited international Internet bandwidth.

## Worldwide Distribution of Knowledge- and Technology-Intensive Industries

As national and regional economies change, the worldwide centers of KTI industries shift in importance. Shifts take place for this entire group of industries and for individual service and manufacturing industries within the group. This section will examine the positions of the United States and other major economies in KTI industries.

Table 6-2
**Indexes for ICT infrastructure for selected countries, by economic sector: 2010**

| Country | ICT infrastructure index | | |
|---|---|---|---|
| | Business | Consumer | Government |
| Developed countries | | | |
| United States | 85 | 57 | 79 |
| Australia | 80 | 53 | 77 |
| Canada | 79 | 48 | 79 |
| France | 60 | 46 | 73 |
| Germany | 59 | 49 | 72 |
| Japan | 63 | 77 | 75 |
| South Korea | 57 | 96 | 88 |
| Sweden | 85 | 72 | 87 |
| United Kingdom | 74 | 50 | 71 |
| Developing countries | | | |
| Brazil | 50 | 64 | 85 |
| China | 23 | 69 | 48 |
| India | 6 | 24 | 39 |
| Iran | 17 | 53 | 32 |
| Malaysia | 60 | 77 | 78 |
| Russia | 52 | 93 | 51 |
| Turkey | 59 | 77 | 80 |
| South Africa | 56 | 52 | 74 |

ICT = information and communications technology

NOTES: Developed and developing countries have separate index scores. Country scores are benchmarked against the highest scoring developed and developing country. Scores are based on a variety of data and metrics. For more information on methodology and data sources, see http://www.connectivityscorecard.org/methodology/.

SOURCE: ICT Connectivity Scorecard 2010, http://www.connectivity scorecard.org/, accessed 15 February 2011.

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## Health and Education Services

International comparison of the health and education sectors is complicated by variations in the size and distribution of each country's population, market structure, and the degree of government involvement and regulation. As a result, differences in market-generated value added may not accurately reflect differences in the relative value of these services.

The United States and the EU are the world's largest providers of education services, with world shares of 32% and 30%, respectively (table 6-1 and appendix table 6-4). Other large economies have comparatively small shares—Japan (7%); China (7%); and the Asia-8, a group of economies consisting of India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand (6%).

The U.S. global share of education services fell 4 percentage points from 36% to 32% during the first decade of the century, whereas the EU's share stayed roughly flat (30%) (table 6-1 and appendix table 6-4). Third-ranked Japan's share fell from 13% to 7% because of stagnant growth. China's global share of education services more than doubled from 3% to 7% to nearly equal Japan's share.

Patterns and trends in the health care sector are similar to those for education—domination of both sectors by the EU and the United States, declining global shares of production in the United States and Japan, and a growing share by China (table 6-1 and appendix table 6-5).

## Commercial Knowledge-Intensive Service Industries

The United States has the largest commercial KI service industries—business, financial, and communications—with $3.6 trillion of value added in 2010 (figure 6-11 and appendix table 6-3). The EU was second at $2.9 trillion, trailed by Japan with $900 billion. China had the largest output among developing countries, nearly equal to Japan, with $700 billion. The Asia-8 region was in fifth place with $600 billion.

From 1995 to 2010, the value added of developing countries grew far faster than in the developed world (figure 6-12 and appendix table 6-3). The value added of developing countries more than quadrupled from $500 billion to $2.3 trillion, whereas value added of developed countries more than doubled from $3.9 trillion to $8.6 trillion. Two factors driving the growth of KI service industries in developing countries are the rapid advancement of living standards in these economies and the growth of international trade in these services. Although these industries remain largely based in developed economies, these factors are helping to build local capacity in the developing world.

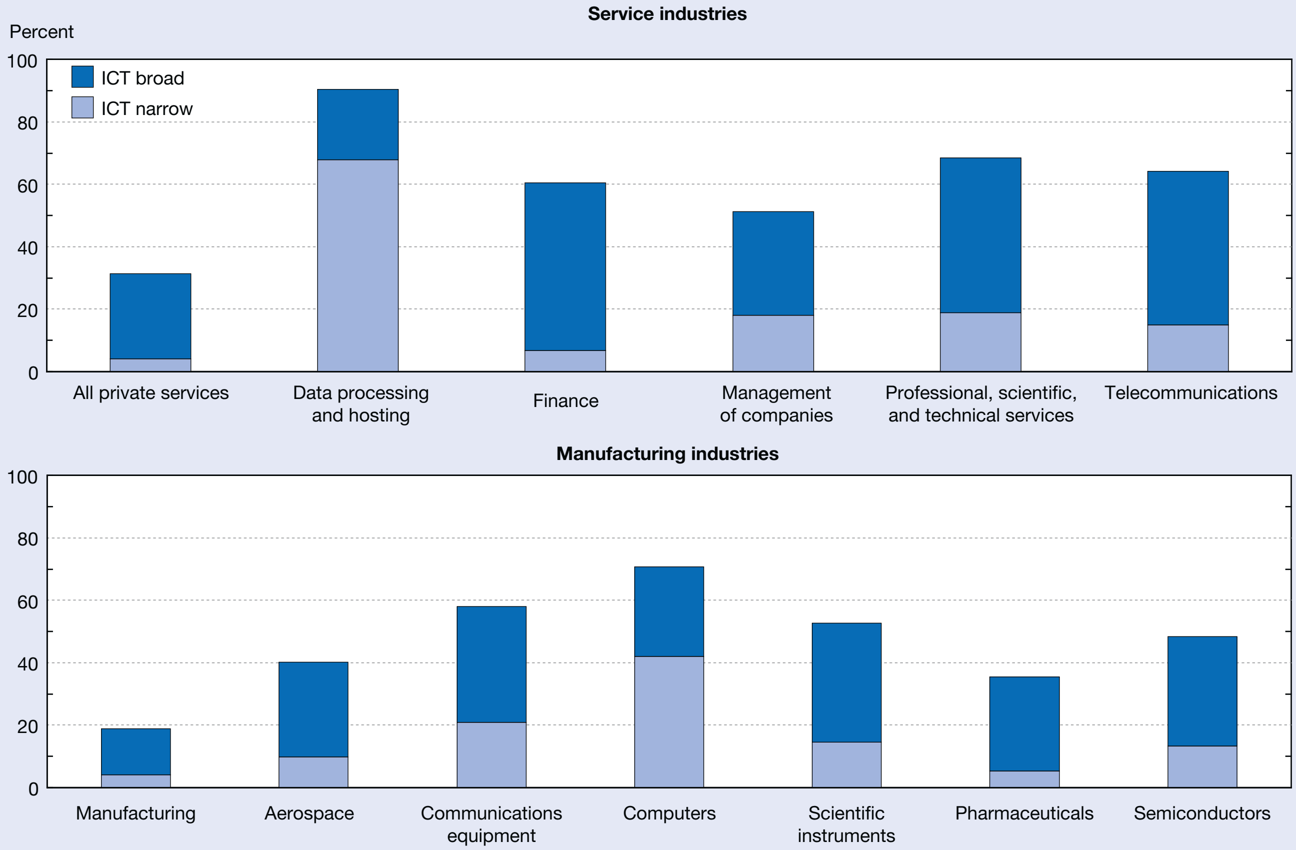
Faster growth of KI services industries in developing countries during the last 15 years resulted in their share of global output rising from 12% to 21% (appendix table 6-3). China's output rose sevenfold, tripling its world share from 2% to 6% (figure 6-11). Brazil, India, and Russia each reached shares of 2%–3%.

Rapidly rising output by China across all commercial KI service industries, combined with the declining Japanese share of worldwide production in these industries through 2007, has substantially altered the national distribution of these services within the Asian region.

Because of the worldwide recession, total global output of commercial KI service industries was stagnant in 2009, compared to 8% growth in 2008 (appendix table 6-3). But developed and developing countries were affected very differently. Output was flat in the developed countries (–0.1%), but it grew by 4% in developing countries (figure 6-13). As a result, a growing share of world output shifted to the developing world. Double-digit growth in China was largely responsible for the difference, but India also increased its output rapidly. The recovery in global output in 2010 (8%) was led by double-digit increases by most major developing economies, continuing the shift in global share from developed to the developing countries. Output of developed countries grew by 5%, with the United States and Japan growing at the same rate. The EU had stagnant growth.

The U.S. share of worldwide commercial KI services, which rose from 1995 to 2001 to reach a peak of 44%, dropped steadily thereafter to 33% in 2010 (figure 6-11 and

Figure 6-10
**Share of U.S. workers with ICT skills, by selected industry: 2009**




ICT = information and communications technology

NOTE: U.S. workers with ICT skills based on those with occupations that use narrow or broadly related ICT skills based on Organisation for Economic Co-operation and Development (OECD) methodology.

SOURCES: Bureau of Labor Statistics, Occupational Employment Statistics, http://www.bls.gov/oes/#data, accessed 15 October 2010; OECD, New Perspectives on ICT Skills and Employment (2005), http://www.oecd.org/dataoecd/ 26/35/34769393.pdf, accessed 15 October 2010.

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appendix table 6-3). The United States had a slight loss in its share of the commercial KI services market during the recent global recession. In 2009, however, U.S. commercial KI services outperformed other U.S. service industries, maintaining their production level while other private services experienced a 1% decline. U.S. commercial KI services grew by 5% in 2010, faster than other services (3%) in that year (figure 6-14).

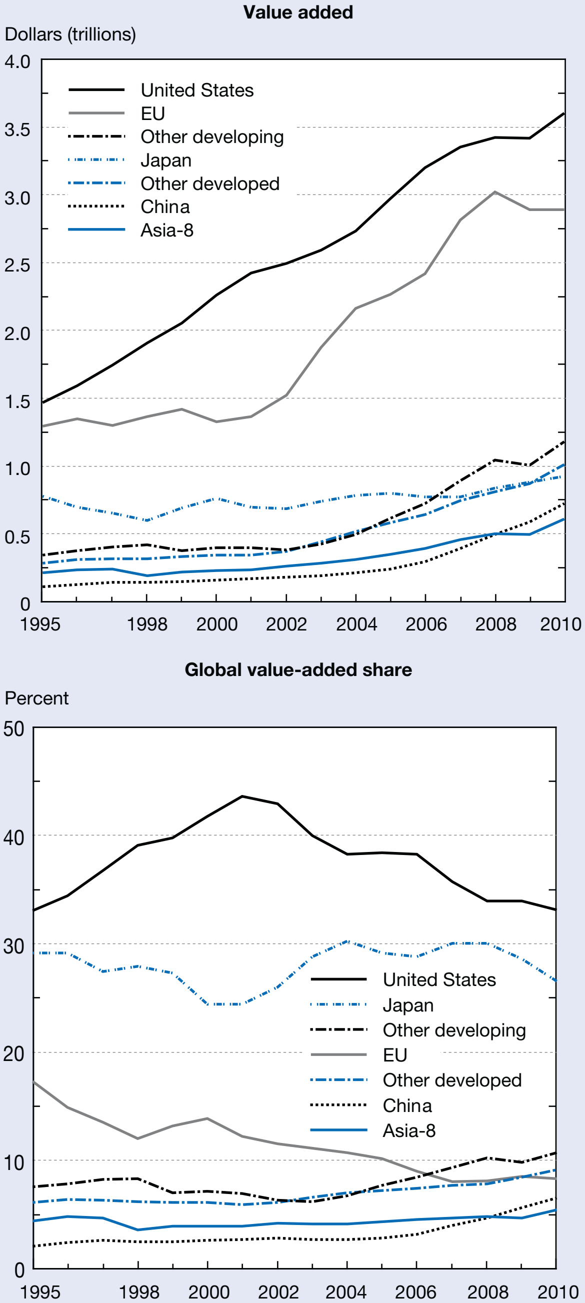
The EU's share of worldwide commercial KI services rose from 24% in 2000 to 30% in 2007–08 before dropping to 26% in 2010 (figure 6-11 and appendix table 6-3). Japan's world share dropped from 17% in 1995 to 8%–9% for the 2006–10 period. (Fluctuations in the shares of the United States, the EU, and Japan may in part reflect changes in the dollar/euro/yen exchange rates.)

Trends in national and regional shares of production in individual commercial KI service industries sometimes varied substantially from the corresponding trends for the group as a whole:

- The U.S. share of the world's communications services declined continuously from 39% in the early 2000s to 26% in 2010 (figure 6-15 and appendix table 6-10).
- The EU's share remained roughly steady in business services and finance for the latter half of the 2000s before falling 2–3 percentage points in 2009–10 to reach 31% for business services and 22% for finance during the recession (appendix tables 6-6 and 6-9). The EU share in communications showed a more pronounced drop from 26% in 2004 to 19% in 2010 (figure 6-15 and appendix table 6-10).

Some large developing economies showed gains in some of these industries but from a low base. Brazil's share in finance rose from 2% to 3% between 2001 and 2010 (appendix table 6-9). Its share in communications more than doubled from 2% to 5% (appendix table 6-10). Russia's share in finance rose from less than 0.5% in 1995 to 2% in 2010. India's share in communications doubled from 1% in 1995 to 2% in 2010.

Figure 6-11
**Value added of commercial KI services, by selected region/country: 1995–2010**




EU = European Union; KI = knowledge-intensive

NOTES: Output of knowledge- and technology-intensive industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services are classified by the Organisation for Economic Co-operation and Development and include business, financial, and communications services. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix table 6-3.

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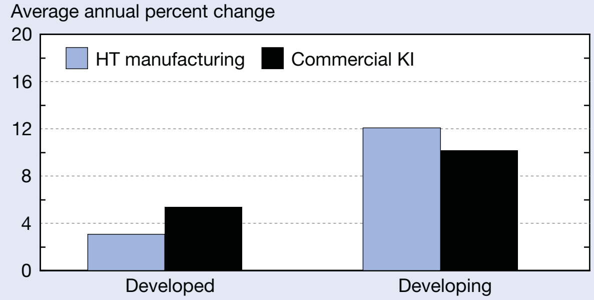
Figure 6-12
**Growth of HT manufacturing and commercial KI industries for developed and developing countries: 1995–2010**




HT = high-technology; KI = knowledge-intensive; OECD = Organisation for Economic Co-operation and Development

NOTES: Output of commercial KI and HT manufacturing industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services are classified by the OECD and include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries are classified by the OECD and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-3 and 6-11.

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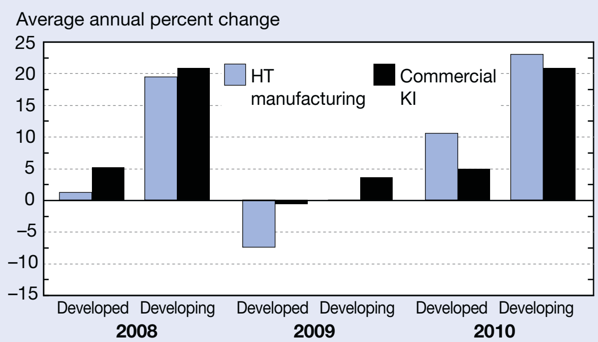
Figure 6-13
**Growth of HT manufacturing and commercial KI services for developed and developing countries: 2008–10**




HT = high-technology; KI = knowledge-intensive; OECD = Organisation for Economic Co-operation and Development

NOTES: Output of commercial KI and HT manufacturing industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services are classified by the OECD and include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries are classified by the OECD and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-3 and 6-11.

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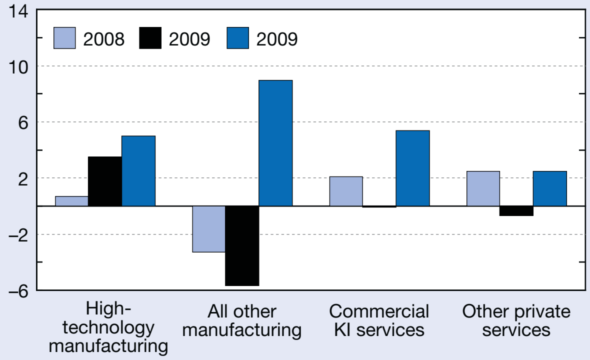
Figure 6-14
**Growth of selected U.S. industries: 2008–09**




KI = knowledge-intensive; OECD = Organisation for Economic Co-operation and Development

NOTES: Output of commercial knowledge-intensive and high-technology manufacturing industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Commercial knowledge-intensive services are classified by the OECD and include business, financial, and communications services. Public knowledge-intensive services include education and health. High-technology manufacturing industries are classified by the OECD and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Growth rate for commercial KI services in 2009 was –0.1 percent.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-3 and 6-11.

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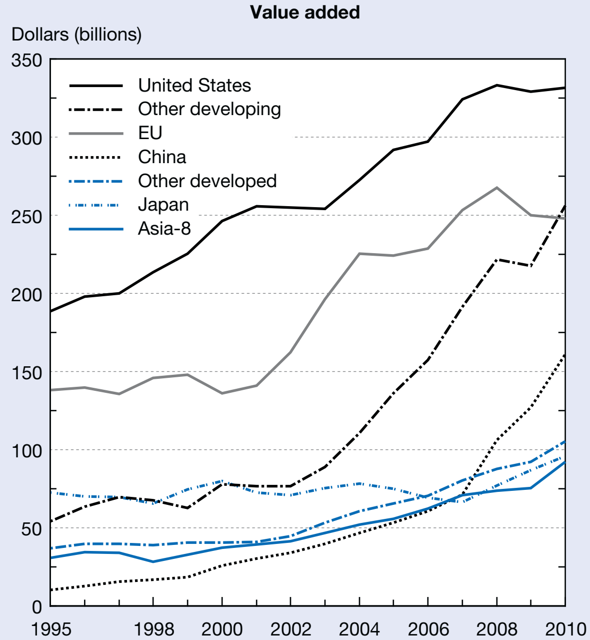
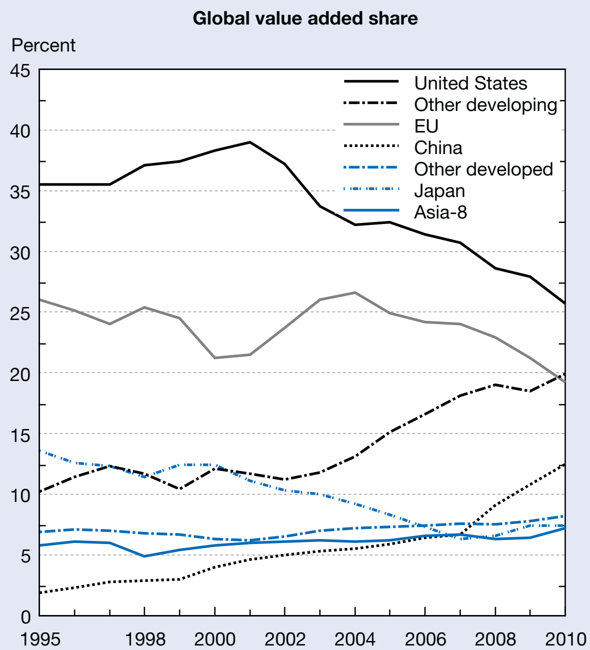
## High-Technology Manufacturing Industries

The United States has the world's largest set of HT manufacturing industries, with $390 billion of global value added in 2010 (figure 6-16 and appendix table 6-11). The EU and China are the second and third largest with about $270 billion and $260 billion, respectively, of global value added in 2010. The EU and China lead the world in apparent domestic consumption of HT goods with the United States close behind (see sidebar, "Apparent Consumption of High-Technology Manufactured Goods"). The Asia-8 and Japan each have HT manufacturing output of about $175 billion.

The dampening effects of the recessions in the early and late 2000s on these industries' output are clearly visible and remarkably similar. Overall worldwide output declined by about 13% from 2000 to 2001, from $850 to $740 billion (appendix table 6-11). Output slipped by 14% in the developed economies but maintained its volume in the developing world. From 2008 to 2009, total world HT manufacturing output declined by 6%. It dropped by 7% for developed economies, but stayed constant for the rest of the world (figure 6-13). Only China's output grew throughout the entire period (figure 6-16). World HT manufacturing output rebounded in 2010, growing at 13%, with developing countries averaging more than 20% growth in their output. Output of developed countries rose by 10%, led by a 30% increase in Japan's output.

Figure 6-15
**Value added for communications services, by selected region/country: 1995–2010**




EU = European Union

NOTES: Output on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix table 6-10.

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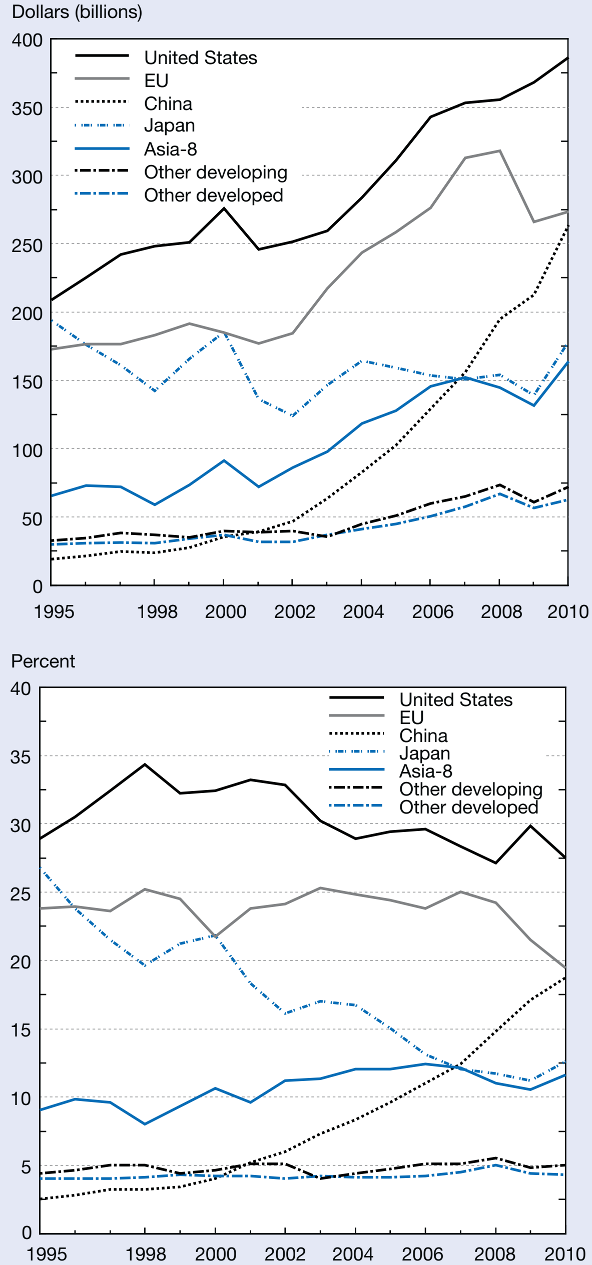
Figure 6-16
**Value added of high-technology manufacturing industries, by selected region/country: 1995–2010**




EU = European Union

NOTES: Output of high-technology manufacturing industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. High-technology manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix table 6-11.

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Output of the United States and EU grew far more slowly, expanding by 5% and 3%, respectively. The relatively less severe effects of the two recessions on developing nations combined with China's rapid, uninterrupted growth to produce global share shifts: from 3% in 1995 to 19% in 2010 for China and from 9% in 1995 to 29% in 2010 for the developing world as a whole (figure 6-16 and appendix table 6-11). The U.S. share declined from 34% in 1998 to 28% in 2010, while the EU's share, long at 25%, dropped to 20% by 2010. Japan's share plummeted from 27% in 1995 to 11% in 2009 before rising to 13% in 2010.

The six HT manufacturing industries contribute uneven value-added amounts. The largest, pharmaceuticals, provided $346 billion, 25% of the global total in 2010. The others, in order, were semiconductors ($312 billion, 22%); scientific and measuring equipment, which includes medical and measuring equipment ($275 billion, 20%); communications equipment ($200 billion, 14%); aircraft and spacecraft ($137 billion; 10%); and computers ($127 billion, 9%) (appendix tables 6-16, 6-17, 6-18, 6-19, 6-20, 6-21, and 6-22). Size variations have not been stable over the 1995–2010 period, in part reflecting steep price declines for computers, semiconductors, and communications equipment.

The U.S. share of global value added was relatively stable in the aircraft and spacecraft, computer, and pharmaceutical industries between 1995 and 2010 (figures 6-17 and 6-18 and appendix tables 6-16, 6-21, and 6-22). The United States is the world's leading producer in aircraft and spacecraft (51% of global value added in 2010) and ties with the EU as the leading producer of pharmaceuticals. The U.S. share in scientific and measuring instruments rose modestly (from 31% to 35%), surpassing the EU in 2010 to become the world's largest producer (appendix table 6-18). The U.S. share fell in communications (from 26% to 20%), and semiconductors (from 25% to 19%) (appendix tables 6-17 and 6-20). Researchers and policymakers have concluded that the location of HT manufacturing and R&D activities overseas may also lead to the migration of higher value activities abroad.

China's communications and semiconductor industries grew more than fivefold over the decade, their world shares climbing from 5%–6% to 17% in semiconductors and 26% in communications equipment (figure 6-18 and appendix tables 6-17 and 6-20). China surpassed the United States and Japan to become the largest producer in communications and overtook the EU to become the third largest in semiconductors, narrowing its gap with the United States. China's rapid growth in these two industries owes much to the establishment in China of manufacturing operations of U.S., EU, and developed Asian-based companies, but Chinese-based companies in these industries are also emerging and successfully competing both domestically and globally. China's computer industry grew even faster than its communications and semiconductor industries, expanding from 4% to 47% of the world total (figure 6-18 and appendix table 6-22). China's dominant position in computer manufacturing has been largely due to its success as the low-cost assembly center of computer components primarily manufactured and designed

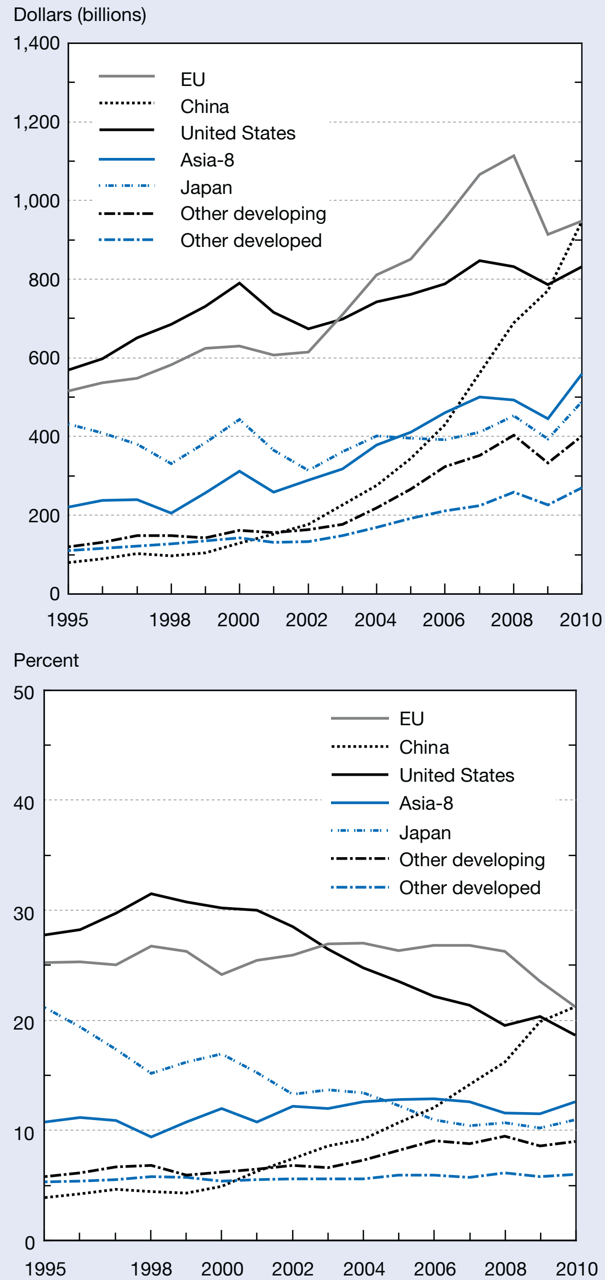
## Apparent Consumption of High-Technology Manufactured Goods

Production of HT goods feeds both domestic and foreign markets. A broad measure of domestic use is provided by adding domestic sales to imports and subtracting exports. However, use so defined encompasses two types of economic activity, consumption of final goods and capital investment for further production (intermediate goods). Available data series do not permit the examination of these two types of activity separately.

Patterns of the world's use of HT manufactures have changed considerably over the past decade. The U.S. share of domestic use, as defined above, fell from 30% in 2000 to 19% in 2010 (figure 6-A). The EU's share stayed broadly the same at 26%–27% over much of the decade before falling to 21% in 2010. The EU overtook the United States in 2003 to become the leading consumer of HT goods between 2003 and 2009. China's share surged from 5% in 2000 to 21% in 2010, overtaking the United States and reaching the EU's level. Japan's share declined from 17% in 2000 to 11% in 2010.

The Chinese trend underscores the difficulty of teasing out final consumption from use as intermediate goods. The strong rise in the Chinese trend is considered by many observers to reflect the rising flow of intermediate goods—often previously produced in China—from other Asian manufacturing centers into China, where they undergo further assembly before being exported to final consumers.

Figure 6-A
**Apparent domestic consumption of high-technology manufacturing industries, by selected region/country/economy: 1995–2010**




EU = European Union

NOTES: Apparent consumption is sum of domestic production and inputs less exports. High-technology manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database (2011).

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in other countries; acquisition of Western computer companies also played a role.[10] China's achievement of designing and building the world's fastest supercomputer—albeit as yet with largely foreign-designed input— indicates its drive to become a global competitor in a range of technologically sophisticated, high-value-added activities (see sidebar, "China's Progress in Supercomputers").

China's growth in other HT industries was also rapid—China more than tripled its world share in pharmaceuticals, scientific instruments, and aircraft and spacecraft (figure 6-17 and appendix tables 6-16, 6-18, and 6-21).

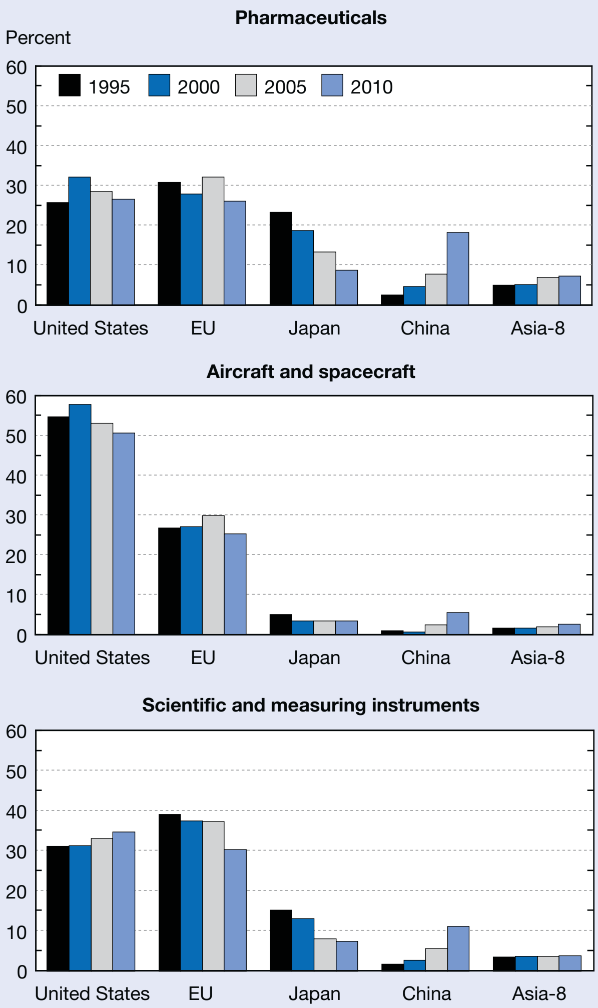
The EU's share stayed roughly stable over the decade in two industries: aircraft and spacecraft (25%) and pharmaceuticals (26%) (figure 6-17 and appendix tables 6-16 and 6-21). Its share fell in computers (from 16% to 8%), communications (from 13% to 9%), semiconductors (from 15% to 12%), and scientific instruments (from 38% to 30%) (figure 6-18 and appendix tables 6-17, 6-18, 6-20, and 6-22).

Japan's share loss, driven primarily by the communications, semiconductor, and computer and office machinery industries, also extended to pharmaceuticals and scientific instruments (figures 6-17 and 6-18 and appendix tables 6-16, 6-17, 6-18, 6-20, and 6-22). However, the decline of Japan's semiconductor industry was interrupted by very strong growth in 2010 that raised its world share from 18% in 2009 to 22% in 2010, resulting in a 7-percentage-point fall in its world share over the decade. This broad downward trend may reflect the Japanese economy's lengthy stagnation and the shift of production to China and other Asian economies.

The Asia-8 rapidly increased its global share in semiconductors from 20% to 26% over the decade, surpassing Japan and the United States to become the largest world producer in this industry (figure 6-18 and appendix table 6-17). The Asia-8's rapid rise was driven by Taiwan and South Korea, which together had a 20% global share. The success of South Korea and Taiwan in this industry reflects both the output of companies based in these locations and investments in manufacturing facilities by Intel and other multinational firms. Many Taiwanese firms have shifted production to mainland China, which may overstate China's global market share and understate Taiwan's.

The Asia-8 slightly increased its share in pharmaceuticals from 5% to 7%, with growth driven by activity in India

Figure 6-17
**Value added for selected manufacturing industries, by global share of selected region/country/economy: 1995, 2000, 2005, and 2010**




EU = European Union

NOTES: Output of industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-16, 6-18, and 6-21.

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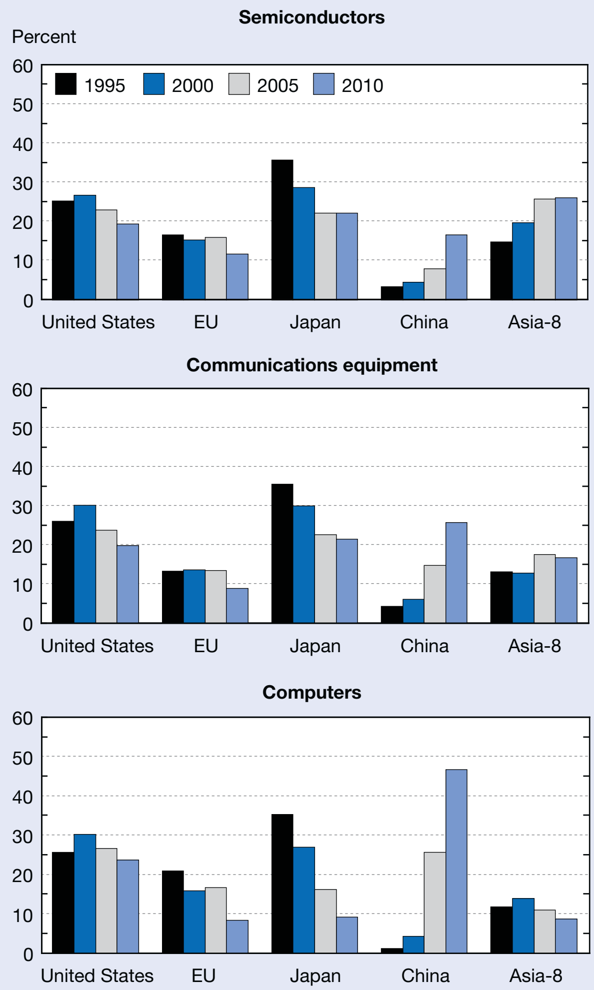
Figure 6-18
**Value added for selected high-technology manufacturing industries, by global share of selected region/country/economy: 1995, 2000, 2005, and 2010**




EU = European Union

NOTES: Output of industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix tables 6-17, 6-20, and 6-22.

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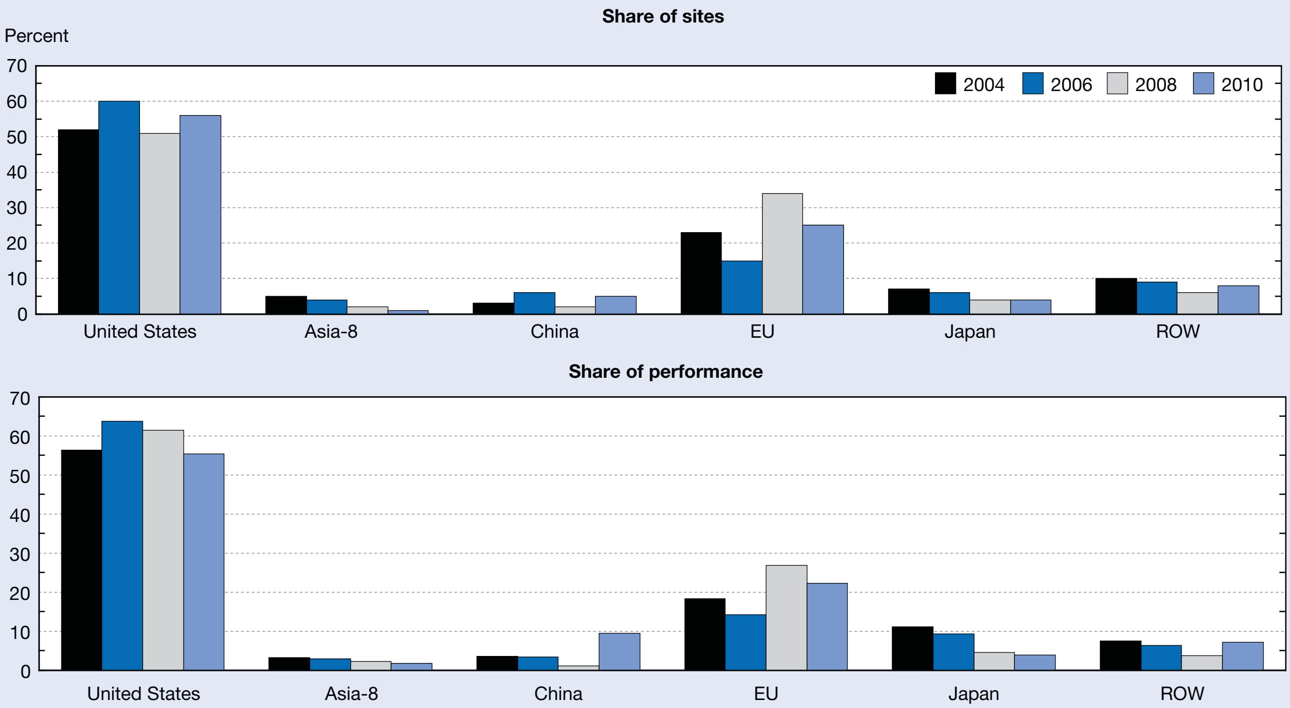
## China's Progress in Supercomputers

The TOP500, an organization composed of computer scientists and industry specialists, has been tracking the world's fastest performing supercomputers since 1993. It provides an annual update with information, including the origin, performance, type of application, and technology of high-performance supercomputers. According to the November 2010 report, China was ranked for the first time as having the world's fastest supercomputer at the National Supercomputing Center in Tianjin. The Tianjin supercomputer uses existing component technology from the United States and other countries with energy-saving technology developed in China.* A second Chinese supercomputer was ranked third, giving China 2 slots in the top 10 supercomputers. The United States was ranked second, and had 4 other supercomputers in the top 10. In 2005, TOP500 had ranked the United States first, and 6 other U.S. supercomputers were ranked in the top 10. China's highest ranking in that year was 26th. The United States continues to dominate in the number of supercomputers ranked in the top 500 and in the number of high-performance supercomputers. China's share of high-performance supercomputers has increased rapidly, from 1% in 2008 to 9% in 2010 (figure 6-B).

*See Ernst (2011) for information on China's Taijin supercomputer.

Figure 6-B
**Top 500 supercomputers by selected region/country: Selected years, 2004–10**




EU = European Union; ROW = rest of world

NOTES: Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. Data on Philippines and Thailand are not available. EU includes Austria, Belgium, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, and the United Kingdom. China includes Hong Kong.

SOURCE: Top 500 Supercomputer Sites, Statistics, http://www.top500.org/drilldown, accessed 15 March 2011.

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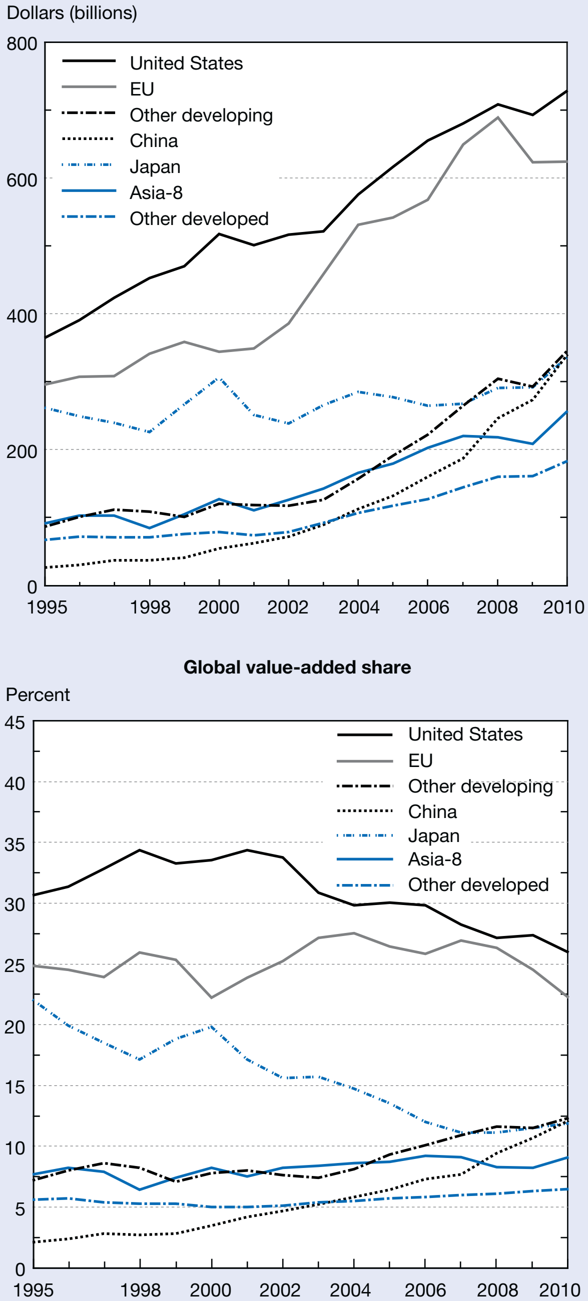
and Singapore (figure 6-17 and appendix table 6-16). Indian firms have become significant world producers, particularly in generic drugs. In addition, U.S. firms and other multinationals have established a presence in India to access the growing consumer market and collaborate with India-based firms. Firms based in India and Singapore have also become contractors for manufacturing and clinical trials conducted by U.S. and EU-based firms.

## Information and Communications Technology Industries

In 2010, the United States had the largest ICT industry with $729 billion (26% global share), closely followed by the EU with $625 billion (22%) (figure 6-19 and appendix table 6-13). China and Japan, each with about $340 billion in value added, tied for third place, with 12% global shares.

Figure 6-19
**Value added for ICT industries, by selected region/ country/economy: 1995–2010**




EU = European Union; ICT = information and communications technology

NOTES: Output of ICT industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. ICT industries are classified by the Organisation for Economic Co-operation and Development and include communications and computer and data processing services and semiconductors and communications and computer manufacturing industries. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: IHS Global Insight, World Industry Service database (2011). See appendix table 6-13.

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The U.S. global share rose from 31% in 1995 to 34% in the early 2000s before falling steadily to reach 26% in 2010 (figure 6-19 and appendix table 6-13). The EU's share remained roughly stable at 26%–27% for much of the 2000s before falling to 22% in 2010. Japan's share fell steeply from 22% in 1995 to reach 11%–12% in the latter half of the 2000s, mirroring its downward trends in share in both HT manufacturing and commercial KI service industries. China's share rose by sixfold from 2% to 12% because of strong gains in its shares of both HT and KI industries. The Asia-8's share was roughly steady at 8% during this period. India's share rose from 0.5% to 1.5%; Brazil's and Russia's shares had similar trends.

## Industries That Are Not Knowledge or Technology Intensive

Science and technology are used in many industries besides HT manufacturing and KI services. Services not classified as knowledge intensive may incorporate advanced technology in their services or in the delivery of their services, albeit at a lower intensity than the KI services discussed above. Manufacturing industries not classified as HT by the OECD may use advanced manufacturing techniques, incorporate technologically advanced inputs in manufacture, and/or perform or rely on R&D. Some industries not classified as either manufacturing or services also incorporate recent science and technology in their products and processes (see sidebar, "Trends in Industries Not Classified as Services or Manufacturing").

### *Non-Knowledge-Intensive Commercial Services*

Commercial services not classified as KI include the wholesale and retail, restaurant and hotel, transportation and storage, and real estate industries. The United States and the EU are the two largest providers in the wholesale and retail industry—the largest of these industries ($7.0 trillion)—and in the real estate and restaurant and hotel industries (table 6-3). The EU is the largest provider in transportation and storage (27% share of global value added), leading the next two economies, the United States and China (14% share each of global value added), by a wide margin. Allowing for fluctuations, the U.S. and EU shares declined and the Asia-8's share remained stable or showed a slightly upward trend between 1995 and 2010. China showed rapid growth, with its shares of global value added at least tripling across all these industries. Japan's global shares fell significantly across all of these industries.

### *Non-High-Technology Manufacturing Industries*

Non-HT manufacturing industries are divided into three categories, as classified by the OECD: medium-high technology, medium-low technology, and low technology. Medium-high technology includes motor vehicle manufacturing and chemicals production, excluding pharmaceuticals; medium-low technology includes rubber and plastic production and basic metals; and low technology includes paper and food product production.

## Trends in Industries Not Classified as Services or Manufacturing

Agriculture, construction, mining, and utilities are not classified as either manufacturing or service industries and are not categorized by their level of technology or knowledge intensity. However, these industries depend on or use science and technology. For example, agriculture relies on breakthroughs in biotechnology, construction uses knowledge from materials science, mining depends on earth sciences, and utilities rely on advances in energy science.

The United States ranks second in construction, mining, and utilities, and third in agriculture as measured by share of global value added among the five major economies—United States, EU, Japan, China, and the Asia-8 (table 6-A). The U.S. share in construction fell from 29% in 2002 to 20% in 2008 and 16% in 2010, in part because of the recession and crisis in the housing sector. The U.S. share remained stable in agriculture and fell slightly in mining and utilities. The EU's share was steady in construction and utilities but fell substantially in mining and agriculture. Japan's share fell sharply in all of these industries. China had gains across all industries, and became the largest producer among the five economies in agriculture and mining. The Asia-8's shares were stable or grew slightly during the 2000s.

Table 6-A
**Share of global value added for selected industries, by region/country/economy: Selected years, 1995–2010**
(Percent distribution)

| Industry and region/country/economy | 1995 | 1999 | 2002 | 2005 | 2008 | 2010 |
|---|---|---|---|---|---|---|
| Agriculture | | | | | | |
| Global value added (current $billions) | 1,108.1 | 1,034.4 | 1,043.6 | 1,385.3 | 2,052.6 | 2,359.0 |
| All countries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 8.2 | 9.0 | 9.0 | 9.2 | 7.8 | 6.5 |
| EU | 22.0 | 19.5 | 17.7 | 16.4 | 14.1 | 10.7 |
| Japan | 9.3 | 7.9 | 6.5 | 5.0 | 3.4 | 3.3 |
| China | 13.1 | 17.3 | 19.2 | 19.8 | 23.6 | 26.3 |
| Asia-8 | 18.8 | 18.7 | 17.9 | 18.7 | 19.0 | 21.2 |
| ROW | 28.6 | 27.6 | 29.7 | 30.9 | 32.1 | 32.0 |
| Construction | | | | | | |
| Global value added (current $billions) | 1,641.6 | 1,627.8 | 1,680.3 | 2,352.2 | 3,174.0 | 3,100.1 |
| All countries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 17.9 | 26.3 | 29.4 | 26.0 | 19.6 | 16.3 |
| EU | 29.7 | 27.7 | 28.1 | 31.2 | 32.3 | 27.2 |
| Japan | 26.5 | 20.6 | 16.1 | 12.3 | 9.1 | 10.1 |
| China | 3.1 | 4.4 | 5.0 | 5.6 | 8.7 | 13.8 |
| Asia-8 | 7.4 | 5.7 | 5.9 | 7.1 | 7.8 | 9.6 |
| ROW | 15.4 | 15.3 | 15.5 | 17.8 | 22.5 | 23.0 |
| Mining | | | | | | |
| Global value added (current $billions) | 494.1 | 481.7 | 657.0 | 1,388.9 | 2,497.9 | 2,358.4 |
| All countries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 15.5 | 17.0 | 16.7 | 13.8 | 12.7 | 11.9 |
| EU | 14.6 | 12.4 | 10.6 | 7.7 | 6.5 | 5.0 |
| Japan | 1.8 | 1.2 | 0.7 | 0.3 | 0.1 | 0.1 |
| China | 4.4 | 6.0 | 6.1 | 7.8 | 11.2 | 14.5 |
| Asia-8 | 7.4 | 7.3 | 7.1 | 6.1 | 5.7 | 7.4 |
| ROW | 56.3 | 56.1 | 58.8 | 64.3 | 63.8 | 61.1 |
| Utilities | | | | | | |
| Global value added (current $billions) | 713.7 | 687.1 | 694.2 | 922.3 | 1,268.6 | 1,298.6 |
| All countries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 24.6 | 25.1 | 26.1 | 22.3 | 20.7 | 21.2 |
| EU | 26.7 | 24.9 | 23.7 | 26.9 | 28.9 | 24.6 |
| Japan | 25.6 | 23.8 | 21.1 | 17.0 | 10.9 | 13.4 |
| China | 2.8 | 4.8 | 6.6 | 8.6 | 12.9 | 15.8 |
| Asia-8 | 5.2 | 5.6 | 6.3 | 6.0 | 4.7 | 5.3 |
| ROW | 15.1 | 15.8 | 16.2 | 19.2 | 21.9 | 19.7 |

EU = European Union; ROW = rest of world

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Industry Service database (2011).

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The share trends in all of these industry segments are generally the same as for HT—share losses for the United States and the EU, larger share losses for Japan, stable or slight increases for the Asia-8, and strong share gains across all segments for China.

♦ **Medium-High-Technology Industries:** These industries produced $2.9 trillion in global value added in 2010. The U.S. share fell from 22% to 14% between 1995 and 2010 (table 6-4), and the EU's share fell from 34% to 24%. Japan's share fell from 24% to 13%. China's share grew more than eightfold from 3% to 26%, as it joined the EU as one of the two largest producers among these economies. The Asia-8's share rose slightly from 6% to 8%.

♦ **Medium-Low-Technology Industries:** The U.S. share of these industries ($3.0 trillion global value added) fell 1 percentage point between 1995 and 2010, to 18% in 2010 (table 6-4). The EU's share fell more steeply, from 31% to 23%. China's share rose nearly sevenfold, from 3% to 20%, making it the second-largest producer among these economies. Japan's share fell from 24% to 10%, its steepest loss among these three segments.

♦ **Low-Technology Industries:** These industries produced $1.2 trillion in global value added in 2010. The U.S. share fell from 25% in 1994 to 19% in 2010, and the EU's share was down more sharply, from 33% to 22% (table 6-4). China's share grew by ninefold, from 3% to 28%.

Table 6-3
**Global value added for selected service industries, by region/country/economy: Selected years, 1995–2010**
(Percent distribution)

| Service industry and region/country/economy | 1995 | 1997 | 1999 | 2001 | 2004 | 2006 | 2008 | 2010 |
|---|---|---|---|---|---|---|---|---|
| Wholesale and retail | | | | | | | | |
| Global value added (current $billions) | 3,692.4 | 3,732.6 | 3,791.4 | 3,836.2 | 4,855.6 | 5,570.3 | 6,775.7 | 6,956.5 |
| All countries/regions/economies | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 26.7 | 29.9 | 32.5 | 34.3 | 30.5 | 29.5 | 24.5 | 24.7 |
| EU | 26.1 | 24.8 | 25.2 | 23.6 | 27.8 | 26.3 | 26.9 | 23.2 |
| Japan | 23.0 | 18.4 | 18.2 | 16.1 | 13.9 | 11.4 | 10.7 | 10.6 |
| China | 2.3 | 3.0 | 3.2 | 3.8 | 3.9 | 4.5 | 6.3 | 8.7 |
| Asia-8 | 5.9 | 6.2 | 5.7 | 5.9 | 6.3 | 7.3 | 7.5 | 8.8 |
| ROW | 16.0 | 17.7 | 15.2 | 16.2 | 17.5 | 20.9 | 24.1 | 24.2 |
| Real estate | | | | | | | | |
| Global value added (current $billions) | 2,592.6 | 2,625.7 | 2,770.6 | 2,899.1 | 3,745.9 | 4,217.9 | 5,165.1 | 5,094.3 |
| All countries/regions/economies | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 31.9 | 35.1 | 36.9 | 40.1 | 35.7 | 35.3 | 32.7 | 31.5 |
| EU | 31.5 | 30.0 | 29.3 | 26.9 | 33.1 | 33.1 | 34.4 | 31.0 |
| Japan | 21.9 | 17.7 | 18.0 | 16.7 | 14.8 | 12.3 | 11.6 | 13.4 |
| China | 1.4 | 1.7 | 1.8 | 2.2 | 2.5 | 3.2 | 4.2 | 6.7 |
| Asia-8 | 3.3 | 3.7 | 3.1 | 3.2 | 3.2 | 3.6 | 3.5 | 3.8 |
| ROW | 10.0 | 11.8 | 10.9 | 10.9 | 10.8 | 12.4 | 13.5 | 13.6 |
| Transport and storage | | | | | | | | |
| Global value added (current $billions) | 1,181.3 | 1,179.6 | 1,199.6 | 1,218.0 | 1,616.9 | 1,876.3 | 2,342.3 | 2,426.5 |
| All countries/regions/economies | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 16.5 | 18.7 | 20.3 | 20.7 | 17.7 | 17.4 | 14.8 | 14.1 |
| EU | 30.6 | 29.8 | 30.7 | 28.8 | 33.3 | 31.7 | 32.4 | 27.2 |
| Japan | 23.7 | 17.8 | 17.6 | 15.9 | 13.4 | 10.6 | 9.8 | 10.5 |
| China | 4.1 | 5.1 | 6.0 | 7.6 | 7.7 | 8.8 | 10.4 | 13.9 |
| Asia-8 | 6.8 | 7.2 | 6.6 | 6.7 | 7.3 | 8.0 | 7.8 | 8.8 |
| ROW | 18.3 | 21.4 | 18.7 | 20.3 | 20.6 | 23.5 | 24.8 | 25.6 |
| Restaurants and hotels | | | | | | | | |
| Global value added (current $billions) | 704.2 | 733.6 | 799.8 | 817.1 | 1,053.7 | 1,202.2 | 1,441.0 | 1,483.3 |
| All countries/regions/economies | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 26.9 | 30.1 | 33.1 | 36.3 | 32.6 | 32.0 | 27.8 | 27.6 |
| EU | 29.0 | 28.1 | 28.4 | 26.9 | 32.2 | 31.6 | 32.6 | 29.4 |
| Japan | 21.2 | 17.5 | 16.8 | 14.9 | 13.1 | 10.9 | 10.7 | 11.8 |
| China | 2.7 | 3.3 | 3.5 | 4.1 | 4.6 | 5.4 | 7.0 | 7.9 |
| Asia-8 | 6.0 | 6.0 | 4.9 | 5.0 | 5.2 | 6.0 | 6.0 | 6.8 |
| ROW | 14.2 | 15.1 | 13.3 | 13.0 | 12.2 | 14.1 | 15.8 | 16.5 |

EU = European Union; ROW = rest of world

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Industry Service database (2011).

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## Trade and Other Globalization Indicators

In the modern world economy, production is more often globalized (i.e., value is added to a product or service in more than one nation) and less often vertically integrated (i.e., conducted under the auspices of a single company and its subsidiaries) than in the past. These trends have affected all industries, but their impact has been particularly strong in many commercial KTI industries. The broader context is the rapid expansion of these industrial and service capabilities in many developing countries, both for export and internal consumption, accompanied by an increasing supply of skilled, internationally mobile workers. (See chapter 3 for a discussion on the migration of highly skilled labor).

This section will focus on international KI services and HT trade and U.S. trade of advanced technology products (ATP). (See "U.S. Trade in Advanced Technology Products" later in this chapter for a discussion of how the U.S. Census Bureau's product-based classification of advanced technology products differs from the OECD's industry-based classification of HT products.) It will also examine several globalization measures of U.S. multinationals in KTI industries.

Trade data are a useful though imperfect indicator of globalization. Trade data are classified by product or type of service, while corresponding production data are classified by industry (see sidebars "Industry and Trade Data and Terminology" and "Product Classification and Determination of Country of Origin of Trade Goods"). An export classified as a computer service may originate from a firm classified as a computer manufacturer. Trade data also cannot provide a precise measure of where value is added to a product or service. For example, China is credited with the full value (i.e., factory price plus shipping cost) even when exporting a smart phone that was assembled in China with inputs and components imported from other countries.

Table 6-4
**Global value added for manufacturing industries, by selected technology level and region/country/economy: Selected years, 1995–2010**
(Percent distribution)

| Manufacturing technology level and region/country/economy | 1995 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 |
|---|---|---|---|---|---|---|---|---|
| Medium high | | | | | | | | |
| Global value added (current $billions) | 1,526.9 | 1,431.8 | 1,459.6 | 1,452.9 | 1,820.9 | 2,114.5 | 2,653.2 | 2,897.1 |
| All countries/regions/economies | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 21.7 | 25.5 | 25.5 | 24.9 | 20.4 | 18.8 | 14.3 | 14.4 |
| EU | 33.7 | 35.0 | 30.1 | 32.2 | 34.9 | 32.7 | 31.6 | 24.2 |
| Japan | 23.6 | 18.4 | 20.8 | 17.4 | 16.7 | 14.4 | 12.5 | 12.5 |
| China | 2.8 | 3.6 | 4.6 | 6.2 | 8.2 | 12.2 | 18.9 | 26.0 |
| Asia-8 | 5.8 | 4.4 | 6.0 | 6.3 | 6.7 | 7.3 | 7.0 | 8.1 |
| ROW | 12.3 | 13.0 | 13.1 | 13.0 | 13.0 | 14.5 | 15.6 | 14.7 |
| Medium low | | | | | | | | |
| Global value added (current $billions) | 1,365.9 | 1,280.8 | 1,328.0 | 1,280.2 | 1,784.1 | 2,198.8 | 2,878.3 | 2,983.2 |
| All countries/regions/economies | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 19.4 | 22.8 | 24.5 | 25.3 | 22.4 | 21.7 | 18.4 | 17.6 |
| EU | 30.8 | 29.3 | 30.1 | 28.0 | 29.7 | 26.8 | 26.4 | 23.3 |
| Japan | 23.5 | 19.8 | 18.9 | 17.4 | 15.4 | 13.4 | 9.6 | 9.8 |
| China | 3.4 | 3.9 | 4.2 | 5.7 | 7.4 | 10.0 | 14.4 | 19.7 |
| Asia-8 | 7.4 | 7.5 | 6.7 | 6.7 | 7.6 | 7.8 | 8.0 | 7.5 |
| ROW | 15.4 | 16.8 | 15.7 | 17.0 | 17.4 | 20.2 | 23.1 | 22.1 |
| Low | | | | | | | | |
| Global value added (current $billions) | 815.6 | 741.3 | 759.7 | 725.0 | 864.8 | 968.2 | 1,160.3 | 1,221.1 |
| All countries/regions/economies | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 24.8 | 29.0 | 30.5 | 29.8 | 26.4 | 24.5 | 19.3 | 18.6 |
| EU | 32.5 | 33.0 | 28.3 | 30.1 | 31.9 | 29.1 | 28.6 | 22.4 |
| Japan | 16.7 | 12.0 | 12.7 | 9.8 | 8.8 | 6.5 | 6.1 | 5.9 |
| China | 3.3 | 4.3 | 5.1 | 6.8 | 9.1 | 14.2 | 20.6 | 27.7 |
| Asia-8 | 7.7 | 5.6 | 7.0 | 7.2 | 6.6 | 6.9 | 6.2 | 6.7 |
| ROW | 15.0 | 16.1 | 16.4 | 16.3 | 17.2 | 18.8 | 19.2 | 18.8 |

EU = European Union; ROW = rest of world

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Technology level of manufacturing classified by Organisation for Economic Co-operation and Development on basis of R&D intensity of output. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Industry Service database (2011).

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Countries whose firms provide these high-value components and services (design, marketing, software development, etc.) are not credited for their contributions (see sidebar, "Tracing the Geography of the Value Chain of Products").

This discussion of trade trends in KI services and HT manufactured products focuses on (1) the world's large, highly developed countries and regions—the United States, the EU, and Japan; (2) China, which is rapidly taking on an increasingly important role in KTI trade; and (3) the Asia-8, which generates a substantial and increasing trade volume within the group and maintains strong trade ties with China.

Both Europe and East Asia have substantial volumes of intraregional trade. This section treats trade within these two regions in different ways. Intra-EU exports are not counted because the EU is an integrated trading bloc with common external trade tariffs and few restrictions

## Tracing the Geography of the Value Chain of Products

Several studies have attempted to estimate more precisely the geographic contribution of the global value chain involved in the production of several electronic goods. These studies essentially show that the largest returns accrue to the firms and countries that harbor special design, engineering, and marketing expertise. Because value-added data are not readily available at the product or firm level, these studies estimate the cost of direct labor, inputs, design, marketing, and distribution and retail (table 6-B).

A study of Apple's iPad estimates that the United States receives 33% of the retail price of the iPad, almost all of it (30%) consisting of Apple's gross profit (figure 6-C). The estimated share for manufacture and assembly of components for the iPad is 23%, largely apportioned to South Korea with smaller distributions to Japan, Taiwan, the EU, and the United States.

China, the location of final assembly, receives an estimated 2% share of the iPad's price (figure 6-C). The study estimates that China's value added is very small because final assembly of these products requires only a few minutes and China's wages for assembly workers are very low compared to those in more developed countries.

Because final assembly of the iPad and other electronic goods manufactured by foreign multinationals yields little value for China, observers claim that bilateral trade statistics are misleading. The large U.S. trade deficit with China in electronic goods is due in part to crediting China for the entire shipping cost of these goods, even though much of the value of these goods derives from imported parts and components from other Asian countries, the EU, and the United States.

A study by Xing (2010) estimates that crediting exports to countries on the basis of their value-added contribution would lower the value of China's exports of Apple iPhones to the United States in 2009 from an estimated $2 billion to less than $100 million. The remaining $1.9 billion would be credited to countries that supply components to China—South Korea, Japan, Germany, and others.

Table 6-B
**Value chain of Apple iPad, by location and activity: 2010**
(Percent)

| Characteristic | Activity | Location | Amount/cost (dollars) | Share of retail price (%) |
|---|---|---|---|---|
| Distribution and retail | Manufacturer's suggested retail price | Worldwide | 499 | 100.0 |
| | Distribution | Worldwide | 75 | 15.0 |
| | Wholesale price (received by Apple) | United States | 424 | 85.0 |
| Value capture | Total value capture | | 238 | 47.7 |
| | U.S. total | United States | 162 | 32.5 |
| | Design/marketing | Apple | 150 | 30.1 |
| | Manufacturing of components | U.S. suppliers | 12 | 2.4 |
| | Manufacturing of components | Japan | 7 | 1.4 |
| | Manufacturing of components | South Korea | 34 | 6.8 |
| | Manufacturing of components | Taiwan | 7 | 1.4 |
| | Manufacturing of components | EU | 1 | 0.2 |
| | Manufacturing of components | Unidentified | 27 | 5.4 |
| Direct labor | Total direct labor | | 33 | 6.6 |
| | Labor to manufacture components | Unidentified | 25 | 5.0 |
| | Labor for final assembly | China | 8 | 1.6 |
| Inputs | Nonlabor costs | Worldwide | 154 | 30.9 |

EU = European Union

NOTES: iPad is configured with 16GB of memory and no cellular access. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Value capture is value added excluding the cost of direct labor, which is the same as gross profit. Detail may not add to total due to rounding.

SOURCE: Linden G, Kraemer KL, Dedrick J. Who profits from innovation in global value chains? Estimates for the iPhone and iPad, Personal Computing Center, University of California–Irvine (2011), unpublished manuscript dated June 15.

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## Tracing the Geography of the Value Chain of Products—continued

Figure 6-C
**Components of value added and value capture**

<table>
<tr><td rowspan="6">Sales price</td><td rowspan="2">Cost of goods sold</td><td>Purchased inputs</td><td></td><td></td></tr>
<tr><td>Direct labor</td><td rowspan="5">Value added</td><td></td></tr>
<tr><td colspan="2">Selling, general, and administrative</td><td rowspan="4">Value capture</td></tr>
<tr><td colspan="2">Research and development</td></tr>
<tr><td colspan="2">Depreciation</td></tr>
<tr><td colspan="2">Net profit</td></tr>
</table>

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Value capture is value added excluding the cost of direct labor.

SOURCE: Dedrick J, Kraemer KL, Linden G, Who Profits from Innovation in Global Value Chains? A Study of the iPod and notebook PCs, Personal Computing Industry Center, University of California–Irvine (2008), http://pcic.merage.uci.edu/index.htm, accessed 7 November 2009.

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on intra-EU trade. By the same token, HT trade between China and Hong Kong is excluded because it is essentially intra-country trade. Intra-Asian trade is counted because it allows the delineation of a developing Asia-8/China trade zone in the absence of the kind of formal structures that bind the EU together.

## Global Trade in Commercial KTI Goods and Services

Exporting goods and services to other countries is one measure of a country's economic success in the global market—the goods and services it produces compete in a world market.

Global trade in commercial KTI goods and services consists of three services—business, communications, and finance—and six HT products—aerospace, communications, computers, pharmaceuticals, semiconductors, and scientific instruments.[11] The data on commercial KI service trade also include trade in royalties and fees, which do not correspond to a specific industry.

The value of commercial KTI exports has risen faster than their global production, resulting in an increase in the export share of production from 12% in 1995 to plateau at 15%–16% in the latter half of the 2000s (figure 6-20). The rise in export intensity indicates the growing importance of international suppliers involved in production of goods and provision of services. Data on multinational companies and cross-border investment likewise indicate growing interconnection among the world's economies.

The global value of commercial KTI exports increased from $1 trillion in 1995 to $3.5 trillion in 2008, then declined to a recession-induced $3.2 trillion in 2009 but rebounded to $3.6 trillion in 2010 (figure 6-20). This mirrored the trend in global output of commercial KTI industries during this period (figure 6-11 and appendix table 6-3). The decline of commercial KTI exports in 2009 was far sharper than in the recession in the early 2000s (figure 6-20).

The EU is the largest exporter of commercial KI goods and services, with $719 billion in 2009 (23% of global value) (figure 6-21). The Asia-8 closely follows with $683 billion. The United States is next largest with $564 billion (18% of global value), followed by China with $500 billion (16% of global value). Japan trails with $199 billion.

The U.S. global share fluctuated between 20% and 23% from 1995 to 2001 before declining to 17%–18% from 2002 to 2009 (figure 6-21). The EU and Asia-8's shares fluctuated between 20% and 23% for much of the period. China's share rose rapidly from 6% to 15% from 1995 to 2006, surpassing Japan in 2003, then rose more slowly to 16% from 2006 to 2009.

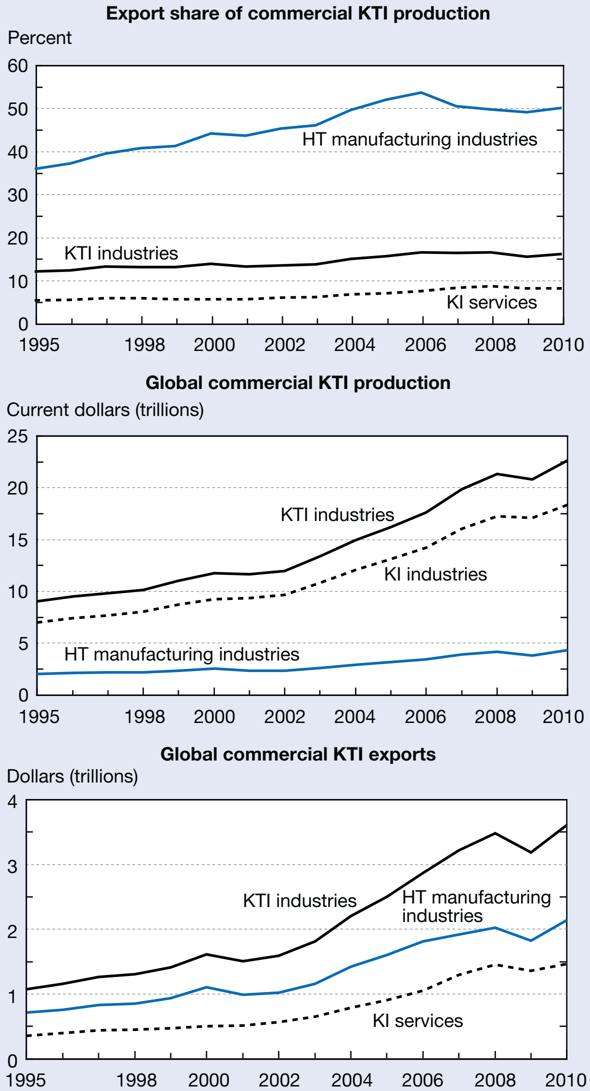
### *Commercial Knowledge-Intensive Services*

Global exports of commercial KI services grew faster than global production of these services over the 15-year period from 1995 to 2010 (figure 6-20). The gradual rise in the export share of commercial KI production (from 5% to 8%) suggests a modest rate of globalization in these service industries, in contrast to the earlier and more rapid pace in HT manufacturing. Advances in ICT technologies and emerging capabilities in other developed and developing countries, such as India, are driving globalization of commercial KI services.

The EU is the largest exporter of commercial KI services with $409 billion in 2009 (30% of global value) (figure 6-22). The United States is the second-largest economy and single largest country exporter with $293 billion in 2009 (22% of global value). The Asia-8 is the third-largest exporter group with $204 billion (15% of global value), with India and Singapore being the major exporters in this region. China is the fourth-largest exporter with $110 billion, although its exports include trade between China and Hong Kong, which is likely substantial.[12] Japan is the fifth largest with $84 billion.

The dollar value of total global exports (excluding intra-EU) of commercial KI services rose almost fourfold over a decade and a half, from $360 billion in 1995 to $1.5 trillion

Figure 6-20
**Global commercial KTI exports and production: 1995–2010**




HT = high-technology; KI = knowledge-intensive; KTI = knowledge- and technology-intensive

NOTES: Production is gross revenue, which includes purchases of domestic and imported materials and inputs. KTI industries include knowledge-intensive services and high-technology manufacturing industries classified by Organisation for Economic Co-operation and Development. Knowledge-intensive services include business, financial, communications, education, and health. Commercial knowledge-intensive services include business, financial, and communications services. Public knowledge-intensive services include education and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. KTI trade consists of trade of four services (business, financial, computer and communications services, and royalties and fees) and five products (aerospace, communications and semiconductors, scientific instruments, computers, and pharmaceutical products). EU exports in KI services for 2010 is estimated.

SOURCES: IHS Global Insight, World Trade Service database (2010); World Trade Organisation, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 November 2010.

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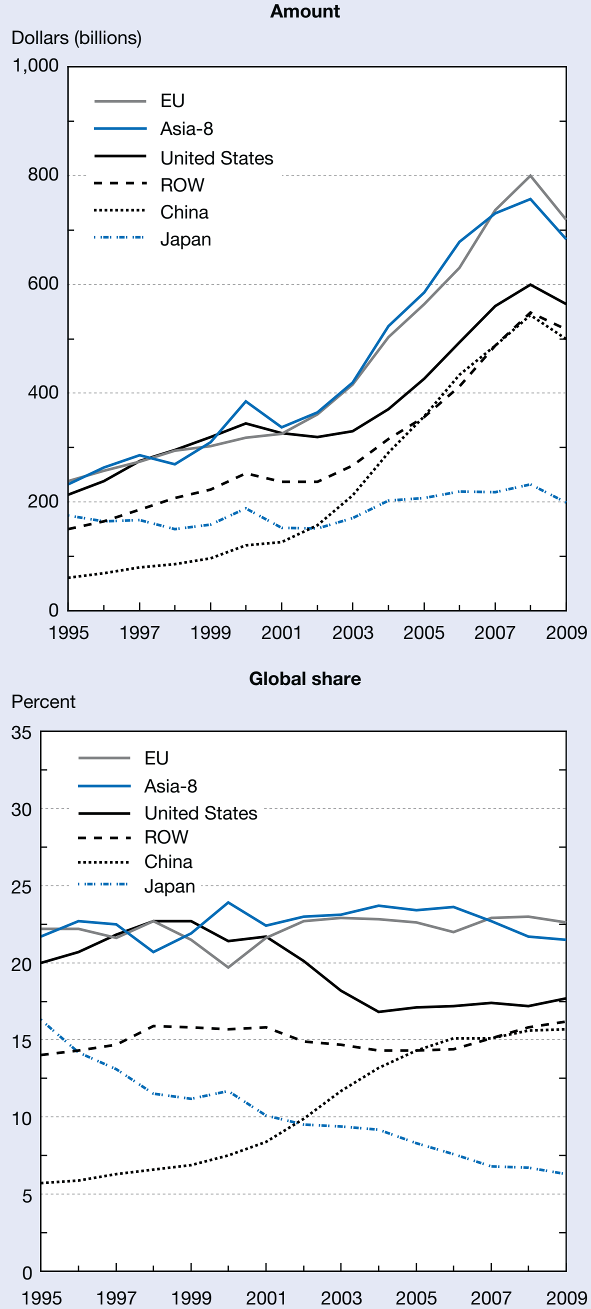
Figure 6-21
**Global commercial KTI exports, by selected region/country/economy: 1995–2009**




EU = European Union; KTI = knowledge- and technology-intensive; ROW = rest of world

NOTES: KTI trade consists of trade of four services (business, financial, computer and communications services, and royalties and fees) and five products (aerospace, communications and semiconductors, scientific instruments, computers, and pharmaceutical products). Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU includes current member countries. Data for China and ROW not available for 2010.

SOURCES: IHS Global Insight, World Trade Service database (2010); World Trade Organisation, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 November 2010.

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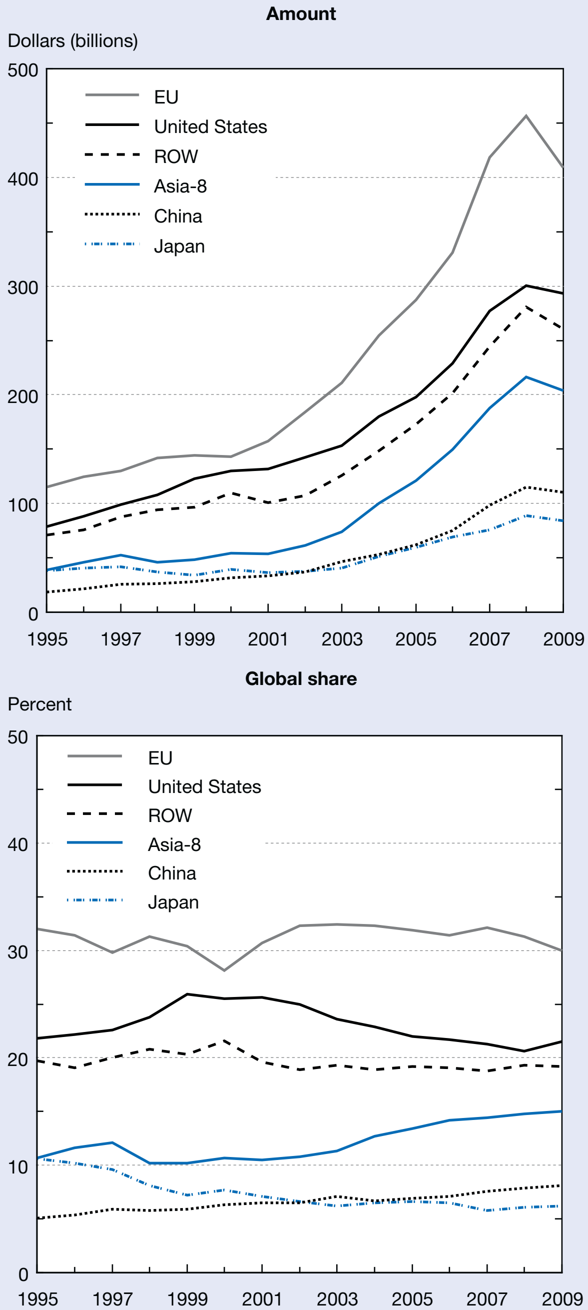
Figure 6-22
**Exports of commercial knowledge-intensive services, by selected region/country/economy: 1995–2009**




EU = European Union; ROW = rest of world

NOTES: Commercial knowledge-intensive trade consists of trade in business, financial, computer and communications services, and royalties and licensing fees. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong and trade between China and Hong Kong. EU includes current member countries. China and ROW not available for 2010.

SOURCE: World Trade Organisation, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 November 2010.

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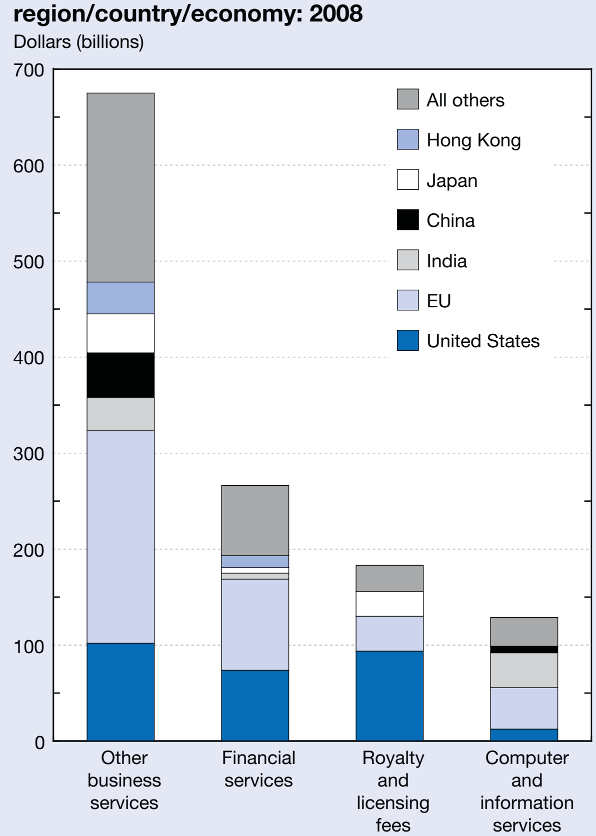
in 2008, before declining to $1.4 trillion in 2009, in contrast to the flattening of output during the earlier recession (figure 6-20). Global exports resumed growth in 2010, returning to their 2008 level ($1.5 trillion).

The U.S. and EU global shares fluctuated at 22%–26% and 29%–31%, respectively, over the period (figure 6-22). The Asia-8's share rose from 11% to 15%, led by India and Singapore. China's share nearly doubled from 5% to 8%, surpassing Japan in 2007. Japan's share declined from 11% to 6% during this period.

Commercial KI service exports comprise four categories: business services (including legal, management, advertising, R&D, and engineering services), valued at $675 billion; financial services (banking and insurance), valued at $267 billion; royalties and licensing fees, valued at $183 billion; and computer and information services, valued at $129 billion (figure 6-23).[13]

Figure 6-23
**Global exports of selected services, by selected region/country/economy: 2008**




EU = European Union

NOTES: EU includes current member countries. Royalty and licensing fees data not available for China and India. Financial services data not available for China.

SOURCE: World Trade Organisation, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 November 2010.

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The EU is the largest world exporter of business services with value added of $222 billion in 2008 (33% of global value) (figure 6-23). The United States is the second largest with $102 billion (15% of global value added), far below the EU's level. China (including Hong Kong) is slightly below the United States with $79 billion (12% of global value added).

The EU is the largest exporter of financial services with $95 billion in 2008 (36% of global value added), closely followed by the United States with $63 billion (28% of global value added) (figure 6-23). Data on China, Japan and the Asia-8 economies show much lower levels of financial services exports.

The United States is the world's largest exporter in royalties and licensing fees with $102 billion (51% of global value) (figure 6-23). The EU and Japan are the second and third largest with $36 billion and $26 billion, respectively. These three economies collectively account for 85% of global value of these exports.

The EU is the largest exporter of communications and information services with $43 billion (33% of global value) (figure 6-23). India is the second-largest exporter with $36 billion (28% of global value), reflecting its strong position in providing these services for companies based in the United States, EU, and other developed countries. The United States is the third largest with $13 billion (10% of global value).

### *Trade Balance Trends in Commercial Knowledge-Intensive Services*

The EU and the United States have enjoyed substantial and rising positive balances in their trade of commercial KI services, particularly over the last decade (figure 6-24). Both exceeded $80 billion in 2009, even as the EU's surplus dropped steeply and the U.S. surplus flattened as a result of the 2008–09 recession. The U.S. surplus rose from $55 billion in 2000 to more than $100 billion in 2007–09, even as the U.S. trade deficit in HT goods deepened during the same period.

The United States has substantial surpluses in royalties and fees ($68 billion) and other business services ($36 billion). It has small deficits in financial services and computer and information services ($2–$3 billion). The composition of the EU's surplus is similar to that of the United States.

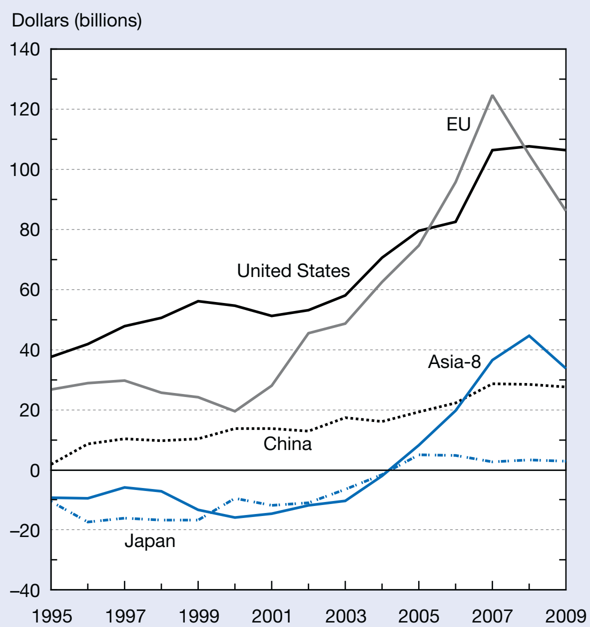
China had a surplus of $28 billion in 2009, up from the $13–$16 billion surplus it had run in the early 2000s (figure 6-24). The Asia-8 as a group had a surplus of $34 billion in 2009 with India having a $32 billion surplus, the largest among these economies (figure 6-24). The rise in India's surplus was driven by its substantial rise in computer and information services. Brazil and Russia have deficits in their KI services trade, ranging up to $29 billion for Russia.

### *High-Technology Goods*

The global production of HT manufacturing industries more than doubled from $2.0 trillion to $4.3 trillion over the last 15 years. The value of HT export goods grew faster than global production, suggesting that globalization has continued in these already highly competitive and geographically dispersed industries. The export share rose from 36% to 53% in 2006 before drifting downward to 50% in 2010 (figure 6-20).

The HT export shares of the major economies—i.e., the percentage of total production that is exported—vary widely, with the shares of the United States and EU and Japan considerably lower than those of China and the Asia-8, the largest global exporters (figure 6-25). The export shares of the United States and the EU each rose about 15 percentage points between 1995 and 2010 to reach 43% in the United States and 38% in the EU. Japan's share stayed roughly stable at 29%. The Asia-8's export share fluctuated between 80% and 90% of their total production. China's export share rose from 63% to 71% from 1995 to 2004 before falling sharply to 43% in 2010, helping to account for the slight decline in the proportion of global HT production that was exported. The decline in China's export share could be a result of growing domestic consumption of these goods, higher labor costs in China that have prompted some relocation of manufacturing facilities to other countries, and higher shipping costs. Conversely, it may reflect the impact of the global recession that caused a sharper decline in China's exports than in production in 2009.

Figure 6-24
**Trade balance in commercial KI services for selected region/country/economy: 1995–2009**




EU = European Union; KI = knowledge-intensive

NOTES: Commercial knowledge-intensive trade consists of trade in business, financial, computer and communications services, and royalties and licensing fees. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU includes current member countries. Data for China not available for 2010.

SOURCE: World Trade Organisation, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 November 2010.

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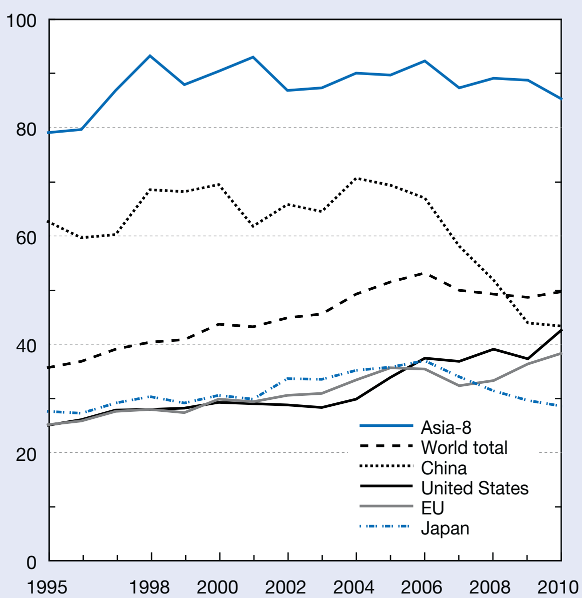
Global exports of HT goods in 2010 were $2.1 trillion, including a combined $1.1 trillion exported by China and the Asia-8 and a collective $800 billion exported by the United States, the EU, and Japan (figure 6-26 and appendix table 6-24). Global HT exports comprised nearly one-fifth of the $11 trillion in exports of all manufactured goods (appendix table 6-25). The largest single exporter in HT manufacturing is the Asia-8 group with $570 billion (27% of global value) (figure 6-26). The second-largest exporter is China with $476 billion (22% of global value). The United States and EU follow China with exports of around $330 billion each (16% of global value). Japan was fifth with exports of $140 billion.

The value of global exports rose from $700 billion in 1995 to $2.0 trillion in 2008 before falling sharply in 2009 to $1.8 trillion, coinciding with the contraction of global HT manufacturing output during the recession (figures 6-16 and

Figure 6-25
**Export share of high-technology manufacturing production, by selected region/country/economy: 1995–2010**




EU = European Union

NOTES: Production is gross revenue, which includes purchases of domestic and imported materials and inputs. High-technology manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. High-technology exports are on a product basis, and include exports of aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU includes current member countries.

SOURCE: IHS Global Insight, World Trade Service database (2011).

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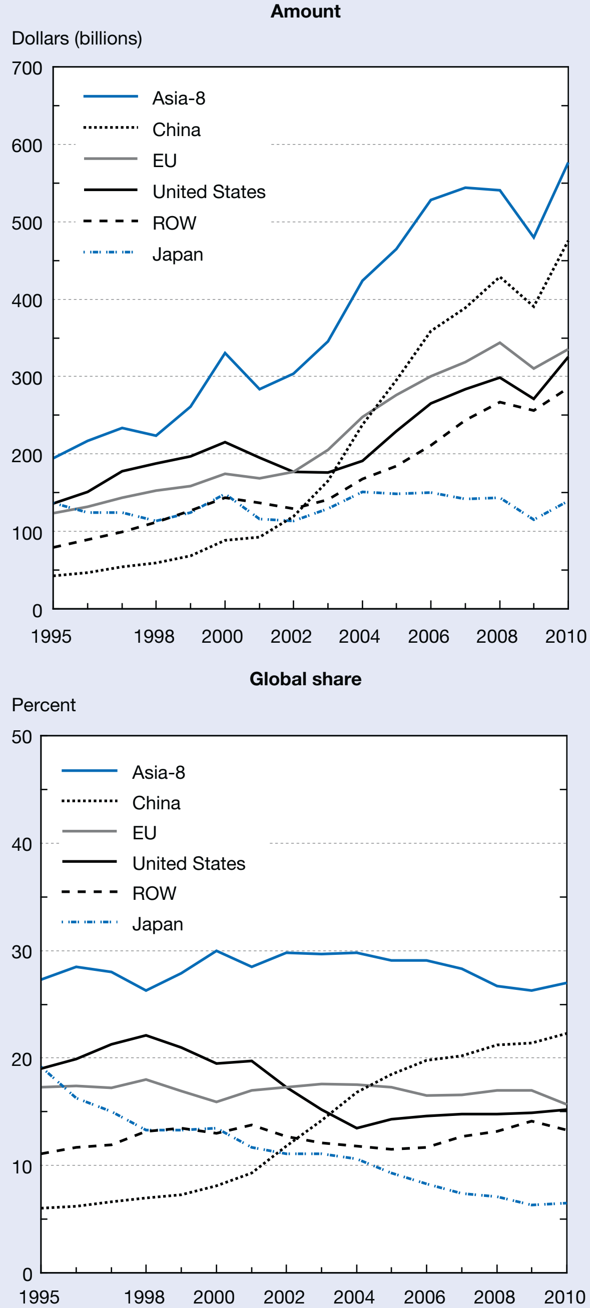
Figure 6-26
**Exports of high-technology goods, by selected region/country/economy: 1995–2010**




EU = European Union; ROW = rest of world

NOTES: High-technology products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix tables 6-24 and 6-32.

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6-26 and appendix table 6-24). Global exports sharply rebounded in 2010 to reach $2.1 trillion, slightly greater than their 2008 levels.[14]

The U.S. share of global HT manufacturing exports rose from 19% to 22% from 1995 to 1998 before declining to a range of 13%–15% from 2003 to 2010 (figure 6-26 and appendix table 6-24). China's share nearly quadrupled from 6% to 22%. The Asia 8's global share fluctuated between 27% and 30% from 1995 to 2010. Japan's share fell sharply from 19% to 7% over the 15-year period.

Among the six HT products, ICT products account for $1.3 trillion (61%) of the $2.1 trillion in global exports. These include communications ($505 billion), semiconductors ($422 billion), and computers ($385 billion) (appendix tables 6-26, 6-27, and 6-28). The others are, in decreasing order: scientific and measuring instruments ($361 billion), pharmaceuticals ($286 billion), and aerospace ($176 billion) (table 6-5 and appendix tables 6-29, 6-30, and 6-31).

The U.S. global export share in computers declined substantially, driving the loss in the U.S. overall ICT export share (table 6-5 and appendix tables 6-26, 6-27, and 6-28). The U.S. share was down by about half, reaching a level of 11%. The United States had a more modest decline in communications (from 13% to 11%) and semiconductors (from 15% to 11%). The EU had comparatively greater declines in communications and semiconductors and a smaller decline in computers. Japan had steep losses across all three goods categories.

China's share rose sharply in communications and computers, becoming the world's largest exporter in these two goods (table 6-5 and appendix tables 6-26 and 6-28). China's share increased from 10% to 39% in communications and from 6% to 45% in computers. China's rise in semiconductors was more modest, increasing from 4% to 10% (appendix table 6-27). The Asia-8's share in communications fluctuated between 24% and 29% and was down in computers (from 39% to 27%). The Asia-8's share in semiconductors rose from 40% to 59%, driven by rapid gains in South Korea and Taiwan. The Asia-8's sizeable export share in ICT goods reflects its role as a manufacturing supplier zone for ICT goods assembled in China.

The U.S. share in scientific and measuring instruments fell slightly from 22% to 19% (table 6-5 and appendix table 6-29). The EU's share also fell slightly, declining from 20% to 18%. Japan's share was down by half from 23% to 12%. The Asia-8 region's share more than doubled from 10% to 22%. China's share rose sharply from 8% to 14%.

The U.S. share in pharmaceutical exports was stable at 16% between 1995 and 2010 (table 6-5 and appendix table 6-30). The EU's share declined from 48% to 44%. China's share was stable at 4%. The Asia-8's share rose from 4% to 6%, driven by gains in India and Singapore.

The United States maintained a dominant position in aerospace exports, with its share rising from 40% in 1995 to 48% in 2005 before dropping to 44% in 2010 (table 6-5 and appendix table 6-31). The EU's share dropped from 40% to 31%.

### *Trade Balance Trends in High-Technology Goods*

The United States had a trade surplus in HT manufactured products throughout the 1980s and early 1990s, in contrast to deficits for other U.S. manufacturing products.[15] Growing U.S. imports in the late 1990s shifted the U.S.

Table 6-5
**Exports of high-technology products, by selected product and region/country/economy: Selected years, 1995–2010**

| Export | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|
| Communications | | | | |
| World ($billions) | 150.5 | 225.2 | 394.9 | 506.9 |
| United States | 13.4 | 13.1 | 7.1 | 9.1 |
| EU | 16.1 | 17.2 | 15.4 | 9.2 |
| Japan | 19.7 | 13.7 | 9.5 | 6.6 |
| China | 10.2 | 12.9 | 28.1 | 38.5 |
| Asia-8 | 29.1 | 24.5 | 26.6 | 23.8 |
| Semiconductors | | | | |
| World ($billions) | 163.5 | 274.0 | 327.9 | 421.8 |
| United States | 15.2 | 17.4 | 13.2 | 11.2 |
| EU | 9.2 | 9.1 | 7.0 | 4.4 |
| Japan | 26.5 | 16.5 | 12.6 | 10.7 |
| China | 3.8 | 4.0 | 7.2 | 10.2 |
| Asia-8 | 39.9 | 46.0 | 55.6 | 58.7 |
| Computers | | | | |
| World ($billions) | 185.7 | 300.6 | 380.8 | 385.1 |
| United States | 19.2 | 15.3 | 9.7 | 10.0 |
| EU | 9.1 | 8.7 | 8.8 | 6.6 |
| Japan | 20.1 | 12.8 | 7.0 | 2.4 |
| China | 5.8 | 10.9 | 34.5 | 45.4 |
| Asia-8 | 39.1 | 44.1 | 34.1 | 27.2 |
| Scientific instruments | | | | |
| World ($billions) | 106.8 | 150.9 | 236.0 | 361.4 |
| United States | 22.4 | 26.0 | 19.7 | 19.1 |
| EU | 20.0 | 19.3 | 21.4 | 17.6 |
| Japan | 22.7 | 19.8 | 15.6 | 11.6 |
| China | 8.1 | 9.0 | 10.6 | 13.9 |
| Asia-8 | 9.5 | 8.7 | 16.0 | 22.0 |
| Pharmaceuticals | | | | |
| World ($billions) | 44.1 | 69.3 | 156.8 | 285.6 |
| United States | 14.6 | 18.6 | 16.4 | 15.6 |
| EU | 47.6 | 47.5 | 50.3 | 44.0 |
| Japan | 4.3 | 4.4 | 2.9 | 2.3 |
| China | 3.5 | 2.7 | 2.5 | 3.9 |
| Asia-8 | 3.5 | 3.7 | 4.5 | 6.4 |
| Aerospace | | | | |
| World ($billions) | 62.4 | 81.9 | 101.9 | 176.5 |
| United States | 39.5 | 48.7 | 48.2 | 44.9 |
| EU | 39.9 | 27.7 | 29.2 | 31.2 |
| Japan | 1.0 | 1.9 | 1.6 | 1.7 |
| China | 0.4 | 0.4 | 0.5 | 0.8 |
| Asia-8 | 2.3 | 1.5 | 2.1 | 3.3 |

EU = European Union

NOTES: Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix tables 6-26–6-31.

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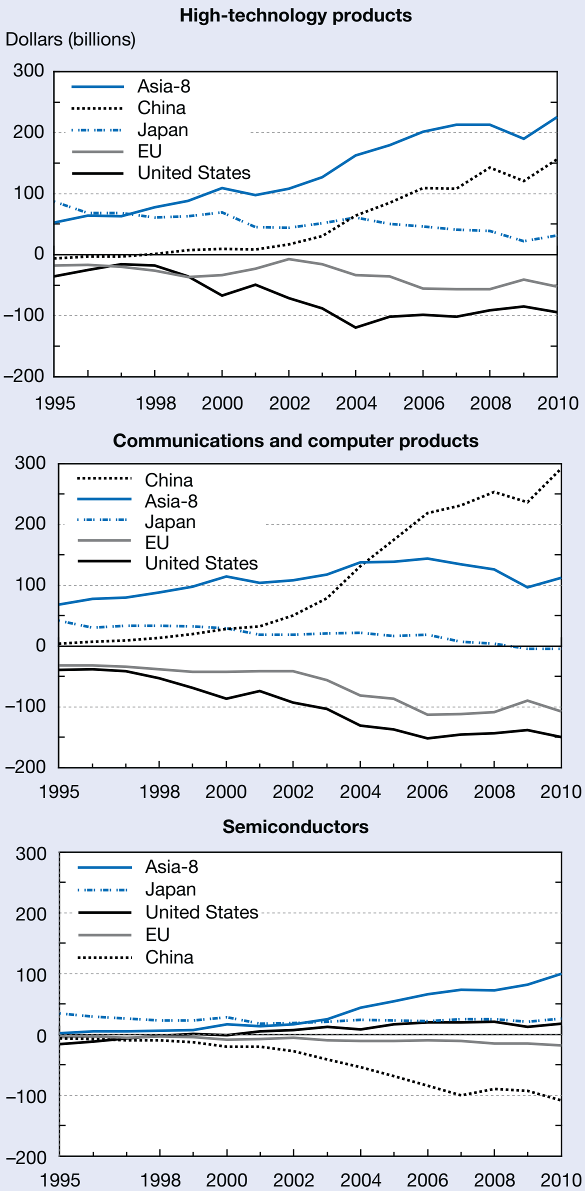
balance into a $67 billion deficit by 2000. After reaching a level of $100–120 billion in 2004–07 prior to the recession, the deficit dropped to $90 billion by 2010 (figure 6-27 and appendix table 6-24).

Figure 6-27
**Trade balance of high-technology products, by selected product and region/country/economy: 1995–2010**




EU = European Union

NOTES: High-technology products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix tables 6-24, 6-26–6-28, and 6-32.

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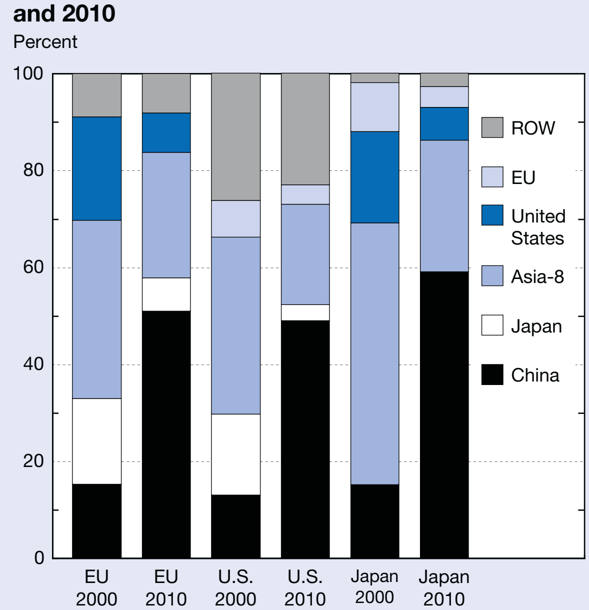
The EU had a small deficit from 1995 to 2005, which widened to $50–$60 billion in 2006-10 (figure 6-27 and appendix table 6-24). Japan's surplus declined from $90 billion to $30 billion over the 15-year period. The other Asian economies also ran surpluses: China's trade position in HT products increased from a small surplus in 2000 to almost $160 billion in surplus in 2010. The Asia-8's trade surplus doubled over the last decade to reach $230 billion in 2010.

Two categories of ICT goods, communications and computers, are largely responsible for producing the substantial shifts in the trade positions of the United States, the EU, Japan, and China (figure 6-27 and appendix tables 6-26 and 6-28). The U.S. deficit in these goods rose from $39 billion in 1995 to nearly $100 billion in 2002 and further widened to $150 billion in 2010; the EU's trend was similar. Japan's trade surplus in these ICT goods fell from $40 billion to a small deficit.

The widening EU and U.S. deficits in these goods and the shrinking Japanese surplus were driven by a sharp rise in their imports from China. This in turn reflected the structural shifts towards Asia in production of these ICT goods (Athukorala and Yamashita 2006, Ng and Yeats 2003, Rosen and Wing 2005). China's share of U.S., EU, and Japanese global imports of these ICT goods rose from 13%–15% in 2000 to 49% or more by 2010 (figure 6-28 and appendix tables 6-33 and 6-34). China's surplus in these ICT goods

Figure 6-28
**U.S., EU, and Japan imports of communications and computer products, by selected origin: 2000 and 2010**




EU = European Union; ROW = rest of world

NOTES: Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix tables 6-32 and 6-33.

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## Product Classification and Determination of Country of Origin of Trade Goods

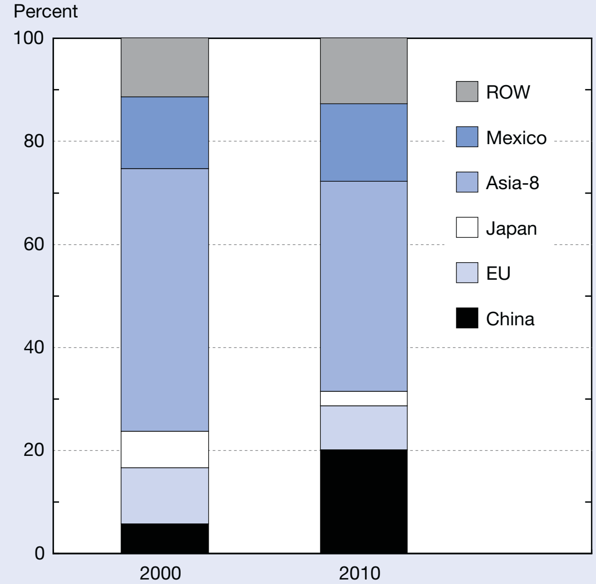
Trade data are based on a classification of goods or services themselves, not the industry that produces them. Data on product trade are recorded at the exporting country's ports of exit and the importing country's ports of entry. Because many imported products are assessed an import duty and these duties vary by product category, a customs agent for the receiving country inspects or reviews the shipment to make the final determination of the proper product code and country of origin. The customs agent assigns a product trade code according to the Harmonized System.*

The value of products entering or exiting a country's ports may include the value of components, inputs, or services classified in different product categories or originating from countries other than the country of origin.

Data on international product trade assign products to a single country of origin. For goods manufactured with international components, the country of origin is determined by where the product was "substantially transformed" into its final form.

*The Harmonized Commodity Description and Coding System, or Harmonized System (HS), is a system for classifying goods traded internationally that was developed under the auspices of the Customs Cooperation Council. Beginning on 1 January 1989, HS numbers replaced schedules previously adhered to in more than 50 countries, including the United States. For more information, see http://www.census.gov/foreign-trade/guide/sec2.html#htsusa.

Figure 6-29
**U.S. exports of semiconductors, by selected destination: 2000 and 2010**




EU = European Union; ROW = rest of world

NOTES: Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix tables 6-32 and 6-34.

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rose from $3 billion in 1995 to $28 billion in 2000, and then leaped to more than $200 billion in 2006 and almost $300 billion in 2010 (figure 6-27 and appendix tables 6-26, 6-27, and 6-28).

In semiconductors, the United States and Japan ran modest surpluses over the last decade (figure 6-27 and appendix table 6-27). The largest market for U.S. exports of semiconductors was the Asia-8, largely South Korea and Taiwan (41% of U.S. exports), with China the second largest at 20%, up sharply from only 6% in 2000 (figure 6-29 and appendix table 6-34). The Asia-8 ran surpluses in semiconductors, reflecting their growing role as suppliers to each other's and China's factories and assembly lines. The surpluses widened over the decade from less than $20 billion in 2000 to $100 billion in 2010, coinciding with rapid growth in Asia-8 exports destined for China for final assembly or manufactured under contract by U.S.- and Japanese-based semiconductor firms (figure 6-30 and appendix table 6-27).

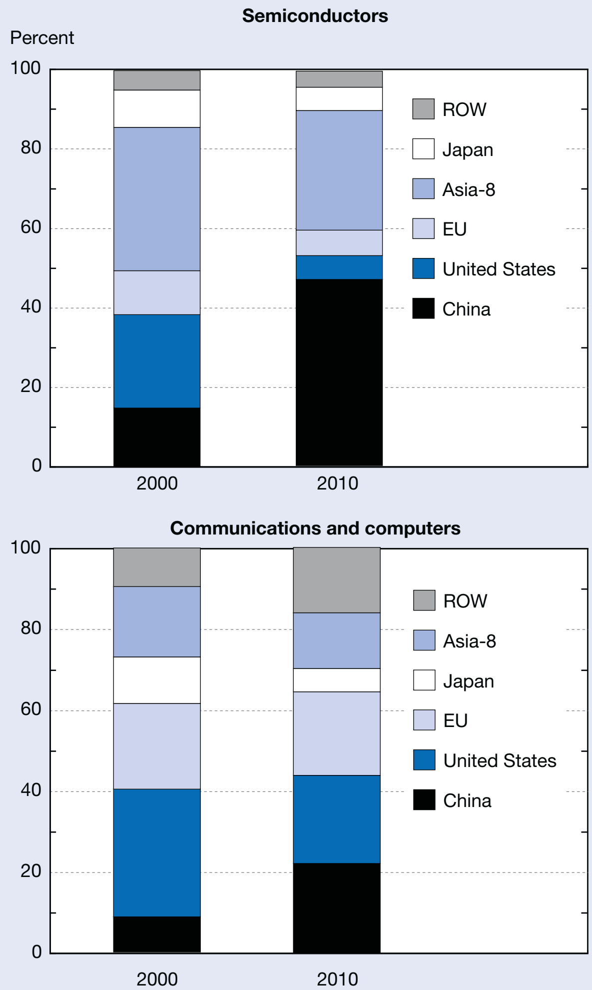
China must import semiconductors for use in its production. Its deficit in semiconductor trade widened from $20 billion in 2000 to $110 billion in 2010, driven by increased imports from the Asia-8 (figure 6-27 and appendix tables 6-27 and 6-34). The Asia-8's share of Chinese semiconductor imports rose from 61% to 77%, with Taiwan accounting for about half of China's imports from this region (figure 6-31).

In aerospace, the United States has run a consistent surplus over the decade and a half from 1995 to 2010 (appendix tables 6-31 and 6-35). The U.S. surplus increased from about $20 billion in the early 2000s to $60 billion in 2010, partially offsetting its growing deficit in communications and computers. The EU ran a small surplus.

In scientific instruments and pharmaceuticals, the United States had small deficits in most years since 1995, while the EU had a surplus in pharmaceuticals that grew from $11 billion in 1995 to $55 billion in 2010 (appendix tables 6-29 and 6-30). The Asia-8's trade position in scientific instruments shifted from a small deficit to surplus in 2005, and steadily grew to $31 billion in 2010. The trend was similar in pharmaceuticals, driven by exports from India and Singapore.

Since 1995, the United States and EU have become more important destinations for pharmaceutical exports from India and Singapore. The U.S. share of India's pharmaceutical exports rose from 5% in 2000 to 29% in 2010, and its share of Singapore's pharmaceutical exports jumped from 5% to 30% during the same period (figure 6-32 and appendix table 6-36). The trend was similar in the EU.

Figure 6-30
**Asia-8 exports of selected goods, by type and destination: 2000 and 2010**




EU = European Union; ROW = rest of world

NOTES: Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix table 6-33 and 6-34.

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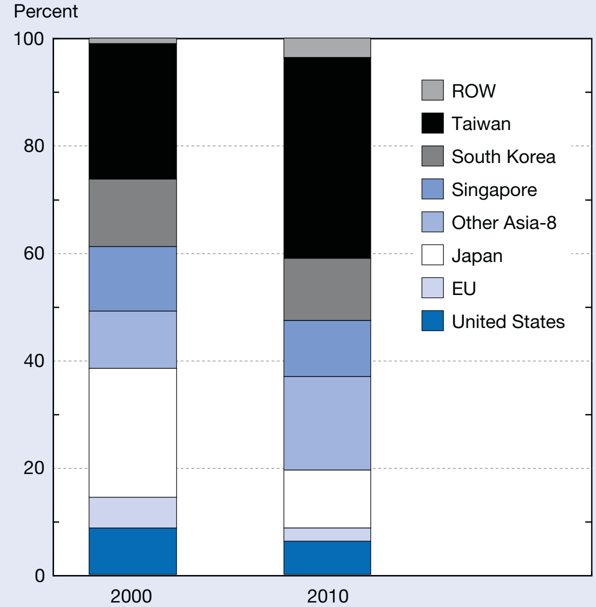
Figure 6-31
**China's imports of semiconductors, by selected origin: 2000 and 2010**




EU = European Union; ROW = rest of world

NOTES: Other Asia-8 includes India, Indonesia, Malaysia, Philippines, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix table 6-34.

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## Trade in Medium- and Low-Technology Manufactured Products

The U.S. export performance in manufactured products associated with less knowledge intensity and less use of R&D provides a context for interpreting its HT trade. In these industries, the United States has world export shares below those of the EU and Asia-8 (across all three categories: medium-high, medium-low, and low technology) and China (medium-low and low technology).

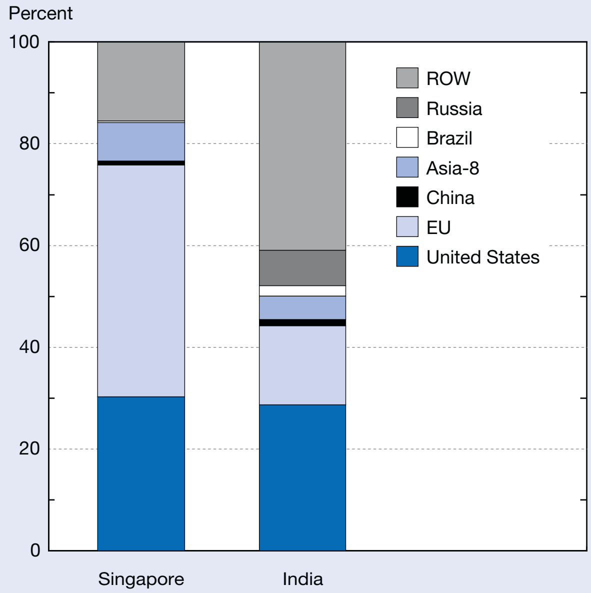
The U.S. share of world exports in medium-high-technology products (i.e., motor vehicles, chemicals, railroad equipment) was 14% in 2010, roughly the same as its share in HT industries (table 6-6), placing it at about the same level as China, Japan, and the Asia-8. The world export shares of these economies are significantly below the leading global exporter, the EU (23% share of global value). The U.S. and EU shares have fallen 3 percentage points over the past decade and a half, while Japan's share has fallen more steeply from 22% to 13%. China has rapidly expanded its share of global exports from 4% to 14% (excluding trade between China and Hong Kong), reaching rough parity with the United States, the Asia-8, and Japan.

The United States has roughly the same share (8%) as Japan in world exports in medium-low-technology products, behind the EU (15%), China (11%), and the Asia-8 (21%) (table 6-6). The U.S. share of global exports of low-technology products in 2010 (11%) placed it well behind all the other major economies except for Japan (2% share). In both of these industry groups, China's world export share expanded greatly since the mid-1990s but not to the same degree as for HT exports.

## U.S. Trade in Advanced Technology Products

The Census Bureau has developed a classification system for internationally traded products based on the degree to which they embody new or leading-edge technologies. This classification system has significant advantages for

Figure 6-32
**India and Singapore's exports of pharmaceuticals, by selected destination: 2010**




EU = European Union; ROW = rest of world

NOTES: Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database (2011). See appendix tables 6-32 and 6-36.

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determining whether products are HT and may be a more precise and comprehensive measure than the industry-based OECD classification.

This system allows a highly disaggregated, focused examination of technologies embodied in U.S. imports and exports. It categorizes advanced technology product (ATP) trade into 10 major technology areas:

- **Advanced materials**—the development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies.
- **Aerospace**—the development of aircraft technologies, such as most new military and civilian airplanes, helicopters, spacecraft (excluding communications satellites), turbojet aircraft engines, flight simulators, and automatic pilots.
- **Biotechnology**—the medical and industrial application of advanced genetic research to the creation of drugs, hormones, and other therapeutic items for both agricultural and human uses.
- **Electronics**—the development of electronic components (other than optoelectronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components (such as capacitors and resistors) that improve performance and capacity and, in many cases, reduce product size.
- **Flexible manufacturing**—the development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention.
- **Information and communications**—the development of products that process increasing amounts of information in shorter periods of time, including computers, videoconferencing, routers, radar apparatus, communications satellites, central processing units, and peripheral units such as disk drives, control units, modems, and computer software.
- **Life sciences**—the application of nonbiological scientific advances to medicine. For example, advances such as nuclear magnetic resonance imaging, echocardiography, and novel chemistry, coupled with new drug manufacturing techniques, have led to new products that help control or eradicate disease.
- **Optoelectronics**—the development of electronics and electronic components that emit or detect light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers.
- **Nuclear**—the development of nuclear production apparatus (other than nuclear medical equipment), including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges. (Nuclear medical apparatus is included in the life sciences rather than this category.)
- **Weapons**—the development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms.

U.S. trade in ATP products is an important component of overall U.S. trade, accounting for about one-fifth of its combined nonpetroleum exports and imports for the past two decades. In 2010, U.S. exports of ATP products were $273 billion (24% of total U.S. goods exports) and imports were $355 billion (23% of total U.S. goods imports) (figure 6-33 and appendix table 6-37). As with world HT product trade accounts, U.S. imports of ATP products have grown faster than exports since the early 1990s. This sent the U.S. trade balance in ATP products into deficit in 2002. The deficit leveled off at $55–60 billion for 2007–09 before reaching a new record high of $82 billion in 2010.

After growing for much of the last decade, exports and imports both fell 10% in 2009 during the global recession (figure 6-33 and appendix table 6-37). Both bounced back in 2010, exports growing 11% and imports growing 18%. Exports returned to their 2008 value, and imports reached a new high of $354 billion.

The growing U.S. trade deficit in these goods reflects not only changing world production and trade patterns but also factors that are hard to measure and cannot be adequately accounted for, including exchange rate movements and new business and production processes.

Table 6-6
**Exports of manufactured products, by selected technology level and region/country/economy: Selected years, 1995–2010**
(Percent distribution)

| Manufacturing technology level and region/country/economy | 1995 | 1998 | 2001 | 2004 | 2006 | 2008 | 2010 |
|---|---|---|---|---|---|---|---|
| Medium high | | | | | | | |
| Global exports (current $billions) | 646.0 | 715.7 | 816.7 | 1,189.6 | 1,523.7 | 1,987.5 | 1,877.4 |
| All countries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 16.5 | 17.0 | 15.7 | 13.3 | 13.9 | 13.1 | 13.7 |
| EU | 25.9 | 25.7 | 24.7 | 25.2 | 23.9 | 24.6 | 23.1 |
| Japan | 22.0 | 19.0 | 17.4 | 16.7 | 15.4 | 14.1 | 12.9 |
| China | 3.8 | 4.9 | 6.6 | 9.3 | 11.5 | 13.4 | 14.3 |
| Asia-8 | 1.5 | 1.3 | 1.8 | 2.7 | 2.9 | 2.7 | 3.4 |
| All other countries | 30.3 | 32.1 | 33.8 | 32.8 | 32.4 | 32.1 | 32.6 |
| Medium low | | | | | | | |
| Global exports (current $billions) | 417.7 | 433.8 | 520.0 | 855.2 | 1,304.6 | 1,976.0 | 1,871.4 |
| All countries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 9.3 | 10.5 | 9.6 | 7.0 | 7.3 | 7.0 | 7.6 |
| EU | 20.8 | 19.7 | 17.0 | 16.8 | 16.8 | 16.1 | 14.8 |
| Japan | 12.6 | 10.4 | 8.3 | 7.7 | 6.6 | 6.4 | 7.4 |
| China | 5.0 | 5.4 | 6.5 | 8.9 | 10.2 | 11.6 | 10.6 |
| Asia-8 | 14.8 | 16.1 | 15.9 | 16.5 | 17.8 | 18.7 | 20.8 |
| All other countries | 37.5 | 38.0 | 42.2 | 42.5 | 41.3 | 39.5 | 37.1 |
| Low | | | | | | | |
| Global exports (current $billions) | 608.5 | 621.8 | 649.5 | 909.7 | 1,075.6 | 1,291.0 | 1,266.0 |
| All countries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| United States | 9.7 | 12.5 | 12.2 | 9.5 | 10.8 | 10.8 | 11.0 |
| EU | 16.4 | 20.1 | 18.7 | 19.5 | 18.4 | 18.3 | 16.5 |
| Japan | 3.5 | 4.0 | 3.7 | 2.7 | 2.5 | 2.1 | 2.1 |
| China | 9.9 | 11.3 | 13.6 | 15.4 | 17.9 | 20.2 | 21.0 |
| Asia-8 | 14.7 | 13.5 | 13.4 | 12.0 | 11.4 | 10.3 | 12.4 |
| All other countries | 45.8 | 38.6 | 38.4 | 40.9 | 39.0 | 38.3 | 37.0 |

EU = European Union

NOTES: Global exports exclude intra-EU exports and exports between China and Hong Kong. EU exports exclude intra-EU exports, and China exports exclude exports between China and Hong Kong. Manufacturing technology level classified by Organisation for Economic Co-operation and Development. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Trade Service database (2011).

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### *U.S. Advanced Technology Product Trade, by Technology*

Four technology areas—ICT, aerospace, electronics, and the life sciences—accounted for a combined share of 85% of U.S. ATP product exports in 2010 (figure 6-34 and appendix tables 6-37, 6-38, 6-39, 6-40, 6-41, 6-42, and 6-43). Aerospace had the largest single share (30%), followed by ICT (28%), electronics (17%), and the life sciences (10%). ICT technologies have generated the largest trade deficits of any technology area—$127 billion in 2010. This deficit in ICT, widening from $35 billion to more than $120 billion over the decade, drove the increase in the U.S. ATP trade deficit.

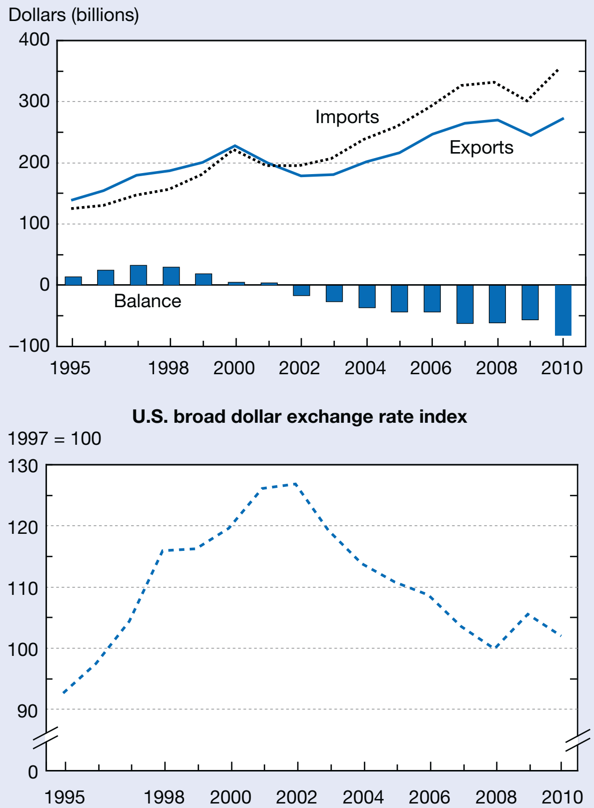
Two technologies, aerospace and electronics, have generated a combined trade surplus of $70 billion in 2010 (figure 6-34 and appendix tables 6-39 and 6-40). The United States is the leading producer of aerospace products; it had a trade surplus of $51 billion in 2010 ($24 billion more than in 2000), as exports jumped from $53 billion to $81 billion and imports increased more moderately from $26 billion to $29 billion. The surplus in electronics was $18 billion in 2010.

### *U.S. Advanced Technology Products Trade, by Region and Country*

About 80% of U.S. ATP exports go to three regions: the EU (24%), Asia (Asia-8, China, and Japan) (36%), and the North American Free Trade Agreement (NAFTA) trade zone (20%) (figure 6-34 and appendix table 6-37).

**China, Japan, and the Asia-8.** China is the single largest U.S. trading partner in both total goods trade and ATP products, exporting $117 billion worth of ATP products to the United States (about one-third of U.S. imports of these products) and importing $30 billion from the United States in 2010 (figure 6-34 and appendix table 6-37).[16] The U.S. deficit in ATP and all products with China is larger than its deficits with any other country. Nearly 90% of U.S. ATP

Figure 6-33
**U.S. trade in advanced technology products and U.S. exchange rate: 1995–2010**




SOURCES: U.S. Census Bureau, Foreign Trade Statistics, Advanced Technology Trade database, http://www.census.gov/foreign-trade/statistics/country/index.html, accessed 15 March 2011; U.S. Federal Reserve, Statistical Releases, Exchange rates and international data, http://www.federalreserve.gov/releases/g17/, accessed 15 March 2011. See appendix table 6-37.

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imports from China are ICT goods (appendix table 6-38). U.S. ATP exports to China include aerospace, electronics, and ICT (appendix tables 6-39 and 6-40).

U.S. ATP data show that ICT imports from China have increased much faster than its exports to China (appendix table 6-38). The steep rise in imports and flat export growth widened the U.S. deficit with China in ICT from $6 billion in 2000 to $87 billion in 2010 (figure 6-34).

ICT products also constituted 40% of all U.S. imports from Japan in 2010 (figure 6-34 and appendix table 6-38). Among U.S. ATP exports to Japan, aerospace accounted for the largest share (34%); life sciences ranked second (22%) (appendix tables 6-39 and 6-40).

The United States exported $36 billion of ICT goods to the Asia-8 and imported $60 billion from this region (figure 6-34 and appendix table 6-38). The $17 billion U.S. deficit with the Asia-8 in ICT consists of $5–$7 billion deficits with Malaysia, South Korea, Taiwan, and Thailand and a small surplus with Singapore. As with China, ICT products constituted the largest share of total U.S. ATP trade with the Asia-8. Important suppliers are Malaysia ($10 billion), South Korea ($13 billion), and Taiwan ($11 billion). U.S. imports of $48 billion and exports of $7 billion produced a deficit with these Asian economies of $41 billion in ICT products in 2010.

**The European Union**. The EU exported $60 billion to the United States and imported $66 billion from it, for a $6-billion U.S. surplus in 2010 (figure 6-34 and appendix table 6-37). Four EU members—France, Germany, the Netherlands, and the United Kingdom (UK)—accounted for nearly 75% of U.S. ATP exports. Three technology areas—aerospace, ICT, and the life sciences—had a combined 75% share of U.S. exports to the EU, with aerospace having the single largest export share (40%) (appendix tables 6-38, 6-39, and 6-41).

The United States had substantial surpluses with the EU in aerospace ($11 billion) and ICT goods ($6 billion) (figure 6-34 and appendix tables 6-38 and 6-39). Important EU customers of aerospace and ICT are France, Germany, and the UK; the Netherlands purchases the most U.S. ICT goods of any EU country. The life sciences produced a $16-billion deficit (appendix table 6-41). Ireland was by far the largest EU supplier of life sciences products to the United States, accounting for more than half of the EU's $27 billion in exports to the United States in 2010. Other substantial suppliers were Belgium, France, Germany, and the UK.

The U.S. trade surplus in ATP goods with the EU narrowed from $16 billion in 2000 to $400 million in 2010, reflecting the deficit in the life sciences, which rose from $6 billion to $16 billion because of accelerating growth of imports (figure 6-34 and appendix tables 6-37 and 6-41).

**NAFTA Trade Zone.** The United States exported $55 billion to Canada and Mexico in 2010 and imported $62 billion from those countries (figure 6-34 and appendix table 6-37). The United States has a $22 billion deficit with Mexico, largely in ICT and optoelectronics, reflecting in part Mexico's duty-free imports of U.S. components and their assembly and free re-export to the United States (appendix tables 6-38 and 6-42). The United States imported $13 billion from Canada and exported $24 billion, resulting in a surplus of $12 billion, largely in ICT goods.[17]

## U.S. Multinational Companies in Knowledge- and Technology-Intensive Industries

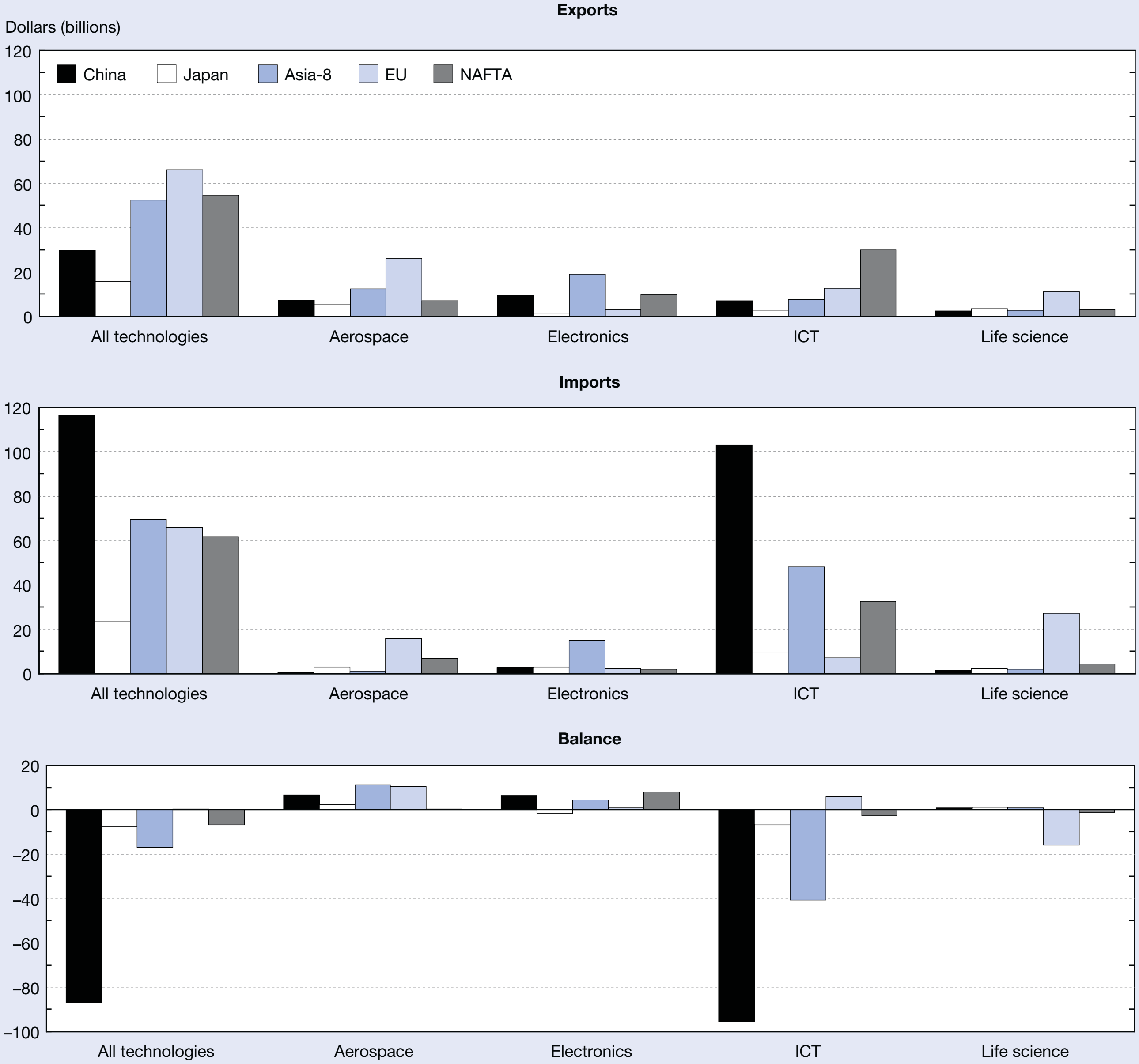
The Bureau of Economic Analysis (BEA) conducts an annual survey of U.S. multinationals that includes firms in KTI industries. The BEA data are not directly comparable with the world industry data used in the previous sections. However, the BEA data provide additional information on the globalization of activity and the employment of U.S. multinationals in these industries.

Since 2000, an increasing proportion of the goods and services produced by U.S. multinational companies in KTI industries has been produced outside the United States. The proportion of jobs in these companies that are outside the United States has likewise increased.

### Commercial Knowledge-Intensive Service Industries

U.S. multinationals in commercial KI service industries generated $722 billion in value added in 2008, of which 79% ($573 billion) occurred in the United States (figure 6-35). Communications ranks first by value added ($264 billion), followed by business services ($261 billion) and finance ($197 billion).[18] The proportion of U.S. value added was highest in communications (90%), followed by Internet and data processing and financial services (76%–77%) and business services (70%). The U.S. share of value added declined across all these industries between 2000 and 2008, suggesting globalization of their production.

Figure 6-34
**U.S. trade in advanced technology products, by selected region/country/economy and technology: 2010**




EU = European Union; ICT = information and communications technology; NAFTA = North American Free Trade Agreement

NOTES: China includes Hong Kong. Asia-8 includes India, Indonesia, Malaysia, Singapore, South Korea,Taiwan,and Thailand. EU includes current member countries. Advanced technology product trade classified by the Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications technology, life sciences, optoelectronics, nuclear, and weapons.

SOURCE: U.S. Census Bureau, Foreign Trade Statistics, Advanced Technology Trade database, http://www.census.gov/foreign-trade/statistics/country/index.html, accessed 15 March 2011. See appendix tables 6-37–6-41.

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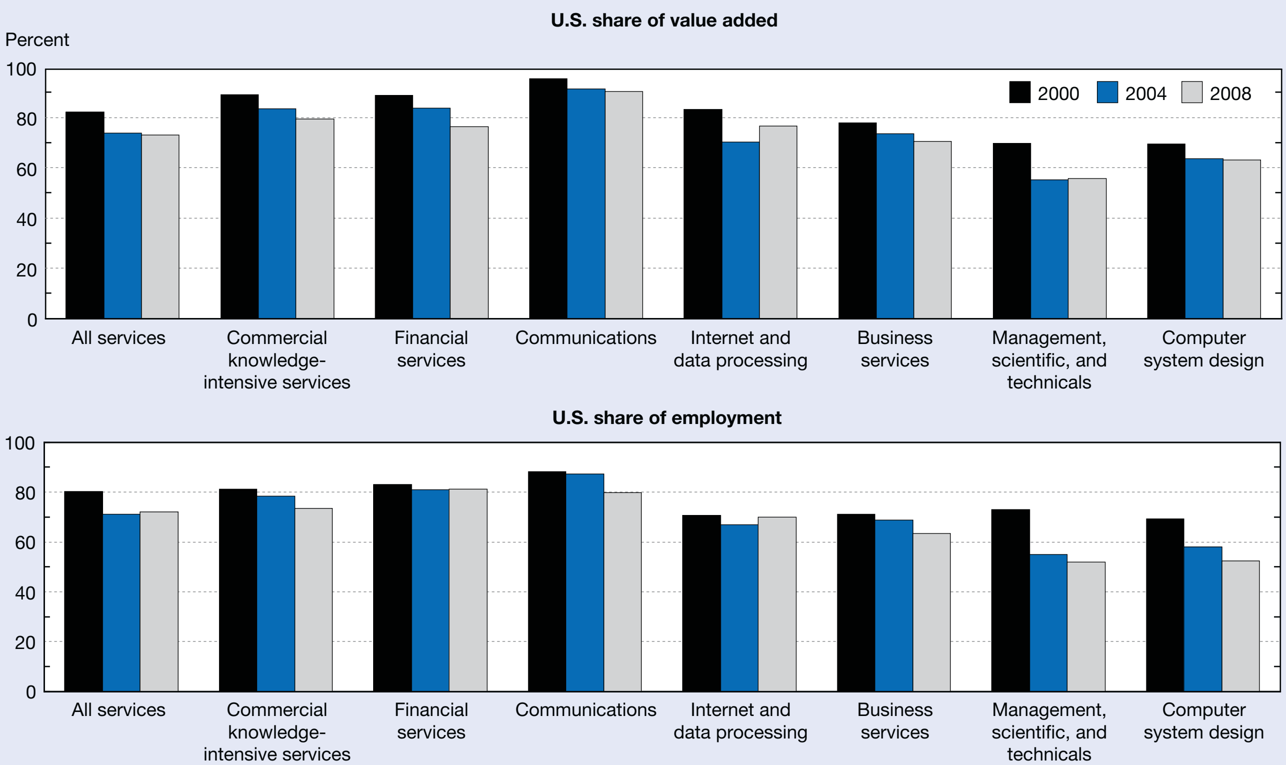
U.S. multinationals in commercial KI service industries employed 5.2 million workers worldwide, of which 3.8 million (73%) were employed in the United States (figure 6-35). U.S. employment was highest in communications services, at 1.4 million, closely followed by 1.3 million employed in business services and 1.0 million employed in financial services. The financial and communications industry employed 81% of their workers in the United States, with business services employing a smaller share of their workers in the United States (63%). Between 2000 and 2008, the U.S. share of employment fell nearly 10 percentage points in business and communications services, but by larger amounts (17%–21%) for computer systems design and management and for scientific, and technical services. The U.S. share in financial services stayed stable.

### *High-Technology Manufacturing Industries*

U.S. multinationals in four of five HT manufacturing industries generated more than $300 billion worldwide in value added in 2008, of which about two-thirds originated in the United States, down from three-quarters in 2000 (figure 6-36). Production in the semiconductor industry was the most globalized, as measured by the distribution between U.S. and foreign value added, with 57% of value added originating from the United States in 2008, down from 77% in 2000. Pharmaceuticals and communication equipment showed a more modest shift, with the U.S. shares of value added falling 5 percentage points to 65% and 81%, respectively. The distribution of value added of the other two industries remained stable between 2000 and 2008.

U.S. multinationals in HT manufacturing employed 2.2 million workers worldwide with 1.3 million workers (about 60%) employed in the United States in 2008 (figure 6-36). More than half (58%) of the semiconductor workforce of half a million workers is employed abroad, the highest share among these industries. Three industries—computers, communications and pharmaceuticals—employ around 40% of their workforce abroad, equal to the average for all manufacturing industries. The navigational and measuring equipment industry has 25% of its workforce abroad, much lower than other industries. The U.S. share of worldwide employment showed little change or increase in computers and

Figure 6-35
**Globalization indicators of U.S. multinationals in commercial knowledge-intensive services: 2000, 2004, and 2008**




NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Commercial knowledge-intensive services are classified by Organisation for Economic Co-operation and Development and include business, financial, and communications. Internet and data processing is part of communications. Management, scientific, and technicals and computer system design are part of business services.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies 1999–2008, http://www.bea.gov/international/di1usdop.htm, accessed 15 December 2010.

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navigational and measuring equipment from 2000 to 2008. The U.S. employment shares in communications equipment fell from 76% in 2000 to 56% in 2008 and in semiconductors fell from to 48% in 2000 to 41% in 2008.

## U.S. and Foreign Direct Investment in Knowledge- and Technology-Intensive Industries

Foreign direct investment (FDI) has the potential to generate employment, raise productivity, transfer skills and technology, enhance exports, and contribute to long-term economic development (Kumar 2007). Receipt of FDI may indicate a developing country's emerging capability and integration with countries that have more established industries. FDI in specific industries may suggest the potential for their evolution and the creation of new technologies.

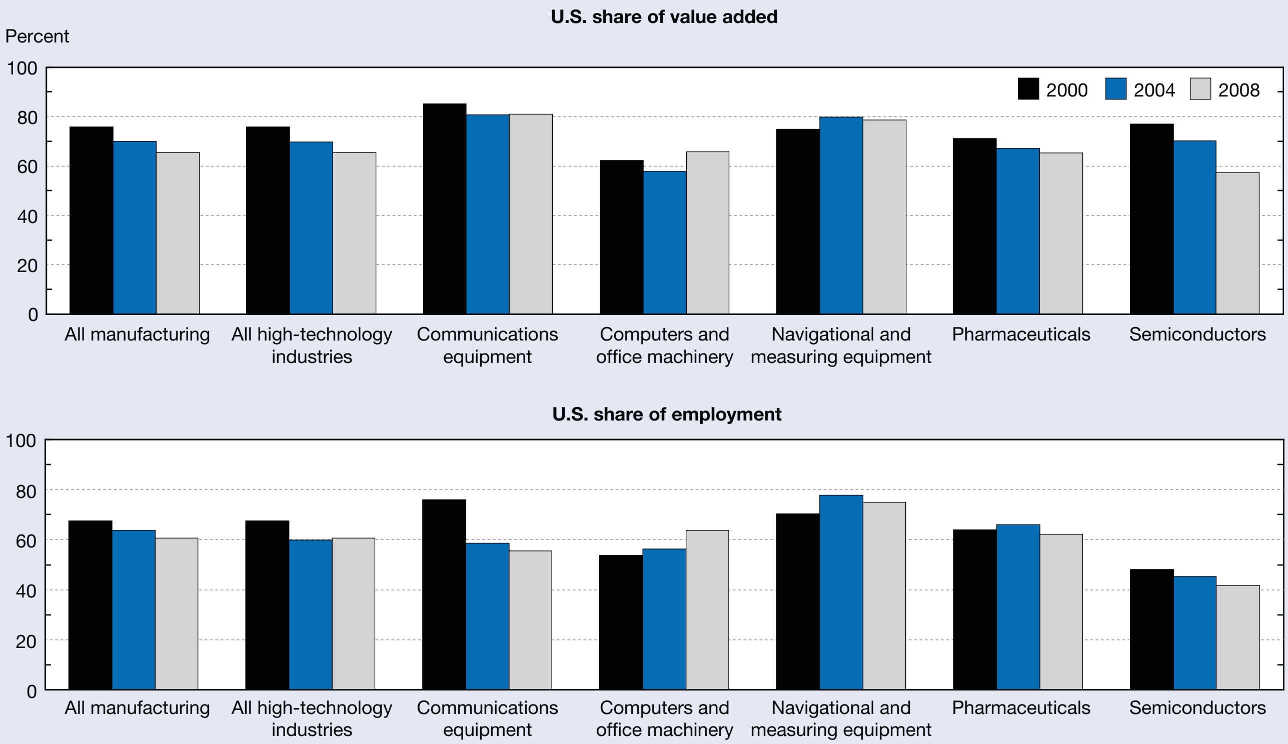
This section uses data from the BEA on U.S. direct investment abroad and foreign investment in the United States in KTI industries. The rising volume of trade by U.S.-based KTI firms has been accompanied by increases in U.S. direct investment abroad and FDI in the United States.

### *U.S. Direct Investment Abroad*

U.S. firms have long invested abroad and have substantial overseas investment positions in both KTI services and manufacturing. The U.S. KI services stock abroad exceeds foreign counterpart investments in the United States; the opposite is the case with HT manufacturing investments (table 6-7). The stock of U.S. direct investment abroad had reached $125 billion in HT manufactures and $1 trillion in commercial KI service industries by 2009.[19] This represented one-quarter of the stock of all U.S. direct overseas investment in all manufacturing industries ($500 billion) and about one-third of U.S. direct overseas investment in all services ($2.8 trillion).

The stock of U.S. direct investment abroad in HT manufacturing industries increased from $87 billion in 2000 to $125 billion in 2009 (table 6-7). Semiconductors and pharmaceuticals have a combined share of 66% of investments in HT industries. The value of pharmaceuticals investments doubled between 2000 and 2009 to reach $51 billion. The investment value in semiconductors rose 25% to reach $31 billion. The stock of investment in the other three HT industries is $10–$13 billion.

Figure 6-36
**Globalization indicators of U.S. multinationals in high-technology manufacturing: 2000, 2004, and 2008**




NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. High-technology manufacturing industries are classified by Organisation for Economic Co-operation and Development and include communications and semiconductors, computers and office machinery, scientific and measuring instruments, and pharmaceuticals.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies 1999–2006, http://www.bea.gov/international/di1usdop.htm, accessed 15 December 2010.

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The stock of U.S. direct investment abroad in commercial KI service industries was $1 trillion in 2009, exceeding one-third of the stock of total U.S. direct investment abroad in all services (table 6-7). Financial services accounted for 86% ($861 billion) of these investments, up from $257 billion in 2000. Business services grew from $61 billion in 2000 to $197 billion in 2009. Within business services, software investments grew from $10 billion to $51 billion, and investment in the professional, scientific, and technical industries more than doubled from $33 billion to $78 billion.

### *Foreign Direct Investment in the United States*

The value of FDI stock in U.S. HT manufacturing industries stood at $222 billion in 2009, up from $133 billion in 2000, larger than the $125 billion FDI stock in U.S. investment abroad (table 6-7). The FDI stock in the U.S. pharmaceuticals industry was $152 billion in 2009, almost 70% of the total. The stock of FDI in pharmaceuticals more than tripled between 2000 and 2009 from $45 billion to $152 billion, coinciding with the acquisition of U.S. drug companies by EU- and India-based firms. The stock of FDI grew rapidly in computers from $3 billion in 2000 to $20 billion in 2009. However, FDI in semiconductors fell from $29 billion to $11 billion during this period, reflecting a relative decline in the U.S. world position in this industry.

FDI stock in U.S. commercial KI service industries was $433 billion in 2009, compared with the $1 trillion in the stock of U.S. investment abroad in these industries (table 6-7). The largest industry was financial services ($292 billion), followed by $84 billion in business services and $56 billion in communications. The stock of FDI in software increased $13 billion to $22 billion over this 9-year period.

## Innovation-Related Indicators of the U.S. and Other Major Economies

The OECD defines innovation as the "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method."[20] Innovation is widely recognized as instrumental

Table 6-7
**Stock of U.S. direct investment abroad and foreign direct investment in the United States, by selected industry: 2000, 2005, and 2009**
(Billions of dollars)

| | U.S. direct investment abroad | | | Foreign direct investment in the United States | | |
|---|---|---|---|---|---|---|
| Industry/service | 2000 | 2005 | 2009 | 2000 | 2005 | 2009 |
| All knowledge- and technology-intensive industries | 420.9 | 723.7 | 1,137.2 | 424.0 | 455.5 | 655.2 |
| Commercial KI services | 333.6 | 631.3 | 1,012.0 | 291.5 | 353.9 | 433.1 |
| Business services | 61.0 | 129.1 | 196.7 | 47.0 | 71.3 | 83.5 |
| Software | 10.4 | 17.5 | 50.8 | 7.4 | 10.9 | 21.6 |
| Professional, technical, and scientific services | 32.9 | 57.2 | 77.5 | 30.5 | 51.5 | 46.1 |
| Architectural and engineering services | 3.1 | 1.9 | 3.5 | 2.6 | 4.2 | 10.2 |
| Computer system design | 15.0 | 28.5 | 33.9 | 13.7 | 9.1 | 9.1 |
| Management, scientific, and technical consulting | 4.3 | 11.0 | 16.5 | 1.0 | 9.9 | 7.9 |
| Communications | 55.5 | 38.1 | 68.3 | 77.5 | 41.0 | 56.4 |
| Finance | 217.1 | 464.0 | 747.0 | 167.0 | 241.6 | 293.2 |
| All services | 874.6 | 1,683.7 | 2,779.6 | 735.9 | 1,026.7 | 1,333.6 |
| High-technology manufacturing | 87.3 | 92.4 | 125.2 | 132.5 | 101.6 | 222.1 |
| Aerospace products and parts | 2.9 | 4.5 | 10.9 | 4.5 | 8.6 | 16.6 |
| Communications equipment | 16.7 | 10.6 | 12.6 | 33.0 | 2.0 | 10.9 |
| Computers and peripheral equipment | 14.1 | 6.3 | 9.3 | 2.5 | 2.2 | 19.5 |
| Navigational, measuring, and other instruments | 3.1 | 6.4 | 9.5 | 19.0 | 10.9 | 12.3 |
| Pharmaceuticals | 25.3 | 38.7 | 51.4 | 44.7 | 65.6 | 151.6 |
| Semiconductors and other electronic components | 25.2 | 26.1 | 31.4 | 28.7 | 12.4 | 11.2 |
| All manufacturing | 343.9 | 430.7 | 541.1 | 480.6 | 499.9 | 790.6 |

KI = knowledge-intensive

NOTES: Knowledge- and technology-intensive industries are commercial knowledge-intensive services and high-technology manufacturing industries. High-technology manufacturing industries and commercial knowledge-intensive services classified by Organisation for Economic Co-operation and Development. High technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, navigational, measuring and other instruments, and pharmaceuticals. Knowledge-intensive services include business, financial, communications, education, and health. Commercial knowledge intensive services include business, financial, and communications services. Communications includes broadcasting, telecommunications, and Internet publishing and broadcasting. Finance does not include depository institutions. Detail may not add to total because of rounding.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad, Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1usdbal.htm, and Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1fdibal.htm, accessed 15 January 2011.

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to the realization of commercial value in the marketplace and as a driver of economic growth.[21] ICT technologies, for example, have stimulated the creation of new products, services, and industries that have transformed the world economy over the past several decades.

This section will present data on how innovation activity varies among U.S. industries, using information from the National Science Foundation's (NSF's) Business R&D and Innovation Survey (BRDIS). The section also includes three indicators of activities that are related to innovation, but do not actually constitute innovation. Two of these, patents and trademarks, are indicators of invention—they protect intellectual property in inventions that can have value for commercial innovations. The third indicator concerns early-stage financing for U.S. HT small businesses, which can be an important milestone in the process of bring new products and services to market.

## Innovation Activities by U.S. Businesses

The NSF BRDIS survey provides innovation indicators that are representative of all U.S.-located businesses with five or more employees. Survey results indicate which kinds of companies introduced new goods, services, or processes between 2006 and 2008.[22] Preliminary data from a 2008 pilot survey suggest that U.S. KTI industries have a much higher incidence of innovation than other industries.

In the U.S. manufacturing sector, four of the six HT manufacturing industries—computers, communications, scientific and measuring instruments, and pharmaceuticals—reported rates of product and process innovation that were at least double the manufacturing sector average (figure 6-37 and appendix table 6-44). Most of these industries reported significantly higher rates of innovation in both goods and services, suggesting that high rates of innovation by manufacturing companies go hand-in-hand with innovations in services.

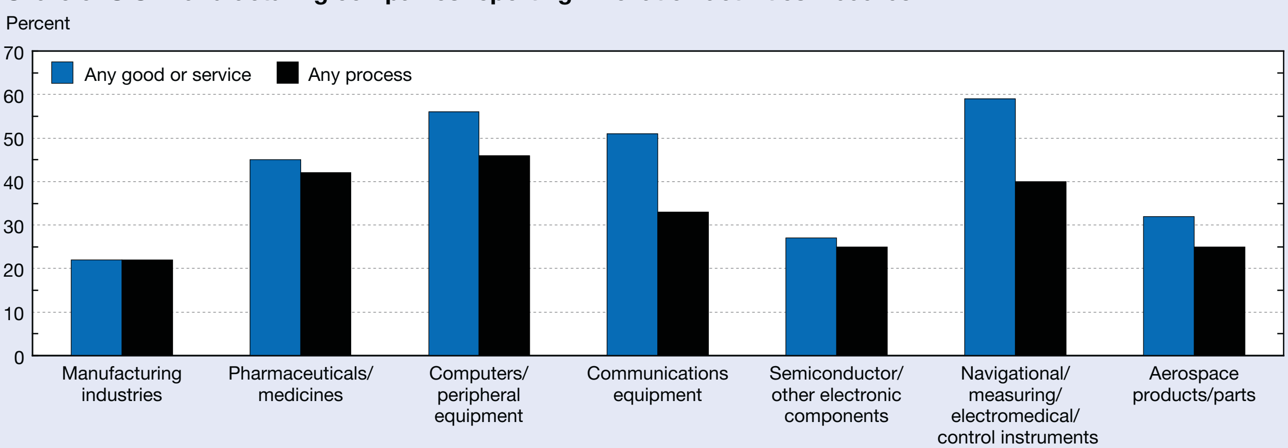
Several of these industries, notably computers, communications, and scientific and measuring instruments, reported significantly higher than average rates of process innovations, particularly in production methods and logistics and delivery methods. Innovation is also higher in several commercial KI service industries in comparison to other service industries (figure 6-38 and appendix table 6-44).[23] Software firms lead in incidence of innovation, with 77% of companies reporting the introduction of a new product or service compared to the 7% average for all nonmanufacturing industries. Innovation is also 2 to 3 times higher than the nonmanufacturing average in the telecommunications/Internet industries. The average rate of innovation in the professional, scientific, and technical industries is close to the nonmanufacturing average, but computer systems design and scientific R&D services reported much higher rates of innovation, comparable to those in the telecommunications/Internet industries.

## Global Trends in Patenting and Trademarks

To foster innovation, nations assign property rights to inventors in the form of patents. These rights allow the inventor to exclude others from making, using, or selling the invention for a limited period in exchange for publicly disclosing details and licensing the use of the invention.[24] Inventors obtain patents from government-authorized agencies for inventions judged to be "new…useful…and…nonobvious."[25]

Patenting is an intermediate step toward innovation, and patent data provide indirect and partial indicators of innovation. Not all inventions are patented, and the propensity to

Figure 6-37
**Share of U.S. manufacturing companies reporting innovation activities: 2006–08**




NOTES: Survey asked companies to identify innovations introduced in 2006 to 2008. Sum of yes plus no percentages may not add to 100% due to item nonresponse to some innovation question items. Figures are preliminary and may later be revised. Data may not be internationally comparable.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2008). See appendix table 6-44.

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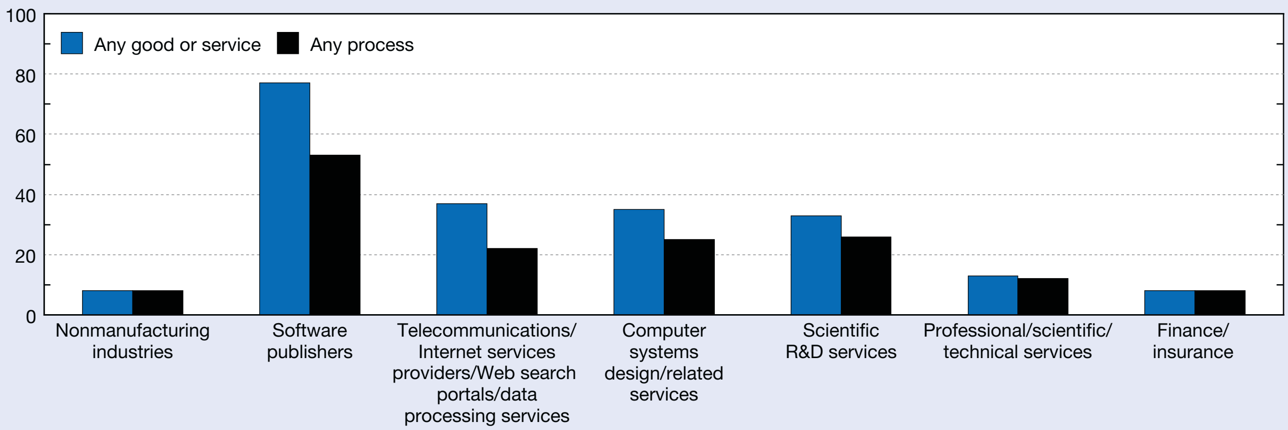
Figure 6-38
**Share of nonmanufacturing U.S. companies reporting innovation, by selected industry: 2006–08**




NOTES: Survey asked companies to identify innovations introduced in 2006 to 2008. Sum of yes plus no percentages may not add to 100% due to item nonresponse to some innovation question items. Figures are preliminary and may later be revised. Data may not be internationally comparable.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2008). See appendix table 6-44.

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patent differs by industry and technology area. Not all patents are of equal value, and not all foster innovation—patents may be obtained to block rivals, negotiate with competitors, or help in infringement lawsuits (Cohen, Nelson, and Walsh 2000).

Indeed, the vast majority of patents are never commercialized. However, the smaller number of patents that are commercialized result in new or improved products or processes or even entirely new industries. In addition, their licensing may provide an important source of revenue, and patents may provide important information for subsequent inventions and technological advances.

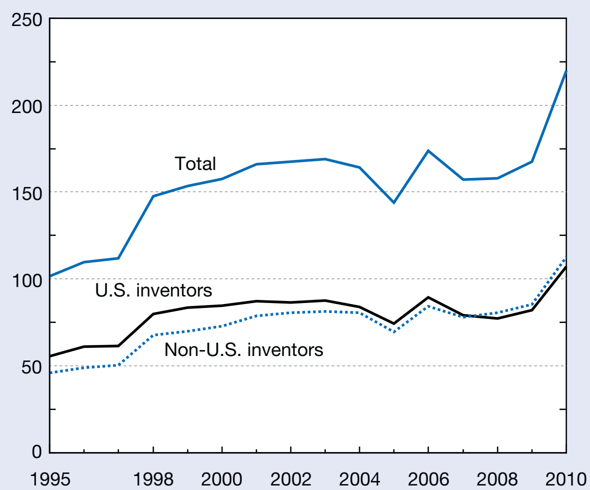
This discussion focuses largely on patent activity at the U.S. Patent and Trademark Office (USPTO). It is one of the largest patent offices in the world and has a significant share of applications and grants from foreign inventors because of the size and openness of the U.S. market.[26] These market attributes make U.S. patent data useful for identifying trends in global inventiveness.

This section also deals with patents filed in all three of the world's largest patenting centers: the United States, the EU, and Japan.[27] Because of the high costs associated with patent filing and maintenance in these three patent offices, inventions covered by these patents are presumed to be valuable.

### Applications for USPTO Grants

The USPTO granted inventors 220,000 patents in 2010, 50,000 more than in 2009 (figure 6-39 and appendix table 6-45). The sharp increase in 2010 may reflect recovery from the recession, along with USPTO efforts to decrease its backlog of patent applications. The United States enacted a new patent law in 2011 aimed in part to reduce the backlog of USPTO patent applications (see sidebar, "New U.S. Patent Law"). The number of U.S. patent grants jumped in the late 1990s, coinciding with a strengthening of the patent system, extension of patent protection into new technology areas through policy changes and judicial decisions during the 1980s and 1990s, and administrative changes (NRC 2004).

Figure 6-39
**USPTO patents granted, by nationality of inventor: 1995–2010**




USPTO = U.S. Patent and Trademark Office

NOTE: Technologies classified by The Patent Board™. Patent grants fractionally allocated between United States and all other countries on basis of proportion of residences of all named inventors.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2011). See appendix tables 6-45 and 6-62.

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Inventors residing in the United States were granted 107,000 patents in 2010, a 30% increase over 2009 (figure 6-39 and appendix table 6-45).[28] The U.S. resident share has gradually fallen since the late 1990s, from 54% to 52% in 2002 and to 49% in 2010. The decline in the U.S. share may indicate increased technological capabilities abroad, globalization, and the increasing recognition by developing countries of the potential value of intellectual property protection in the United States.

The overall growth of patent grants, accompanied by a decline in the U.S. share in these grants over the past two decades, reflects a marked increase in patents granted to non-U.S. countries. The USPTO granted 112,000 patents to non-U.S. inventors in 2010 compared to 46,000 in 1995 (figure 6-39 and appendix table 6-45). The EU, Japan, and the Asia-8 are the main recipients, with a collective share of nearly 90% of patents granted to all non-U.S. inventors (figure 6-40).

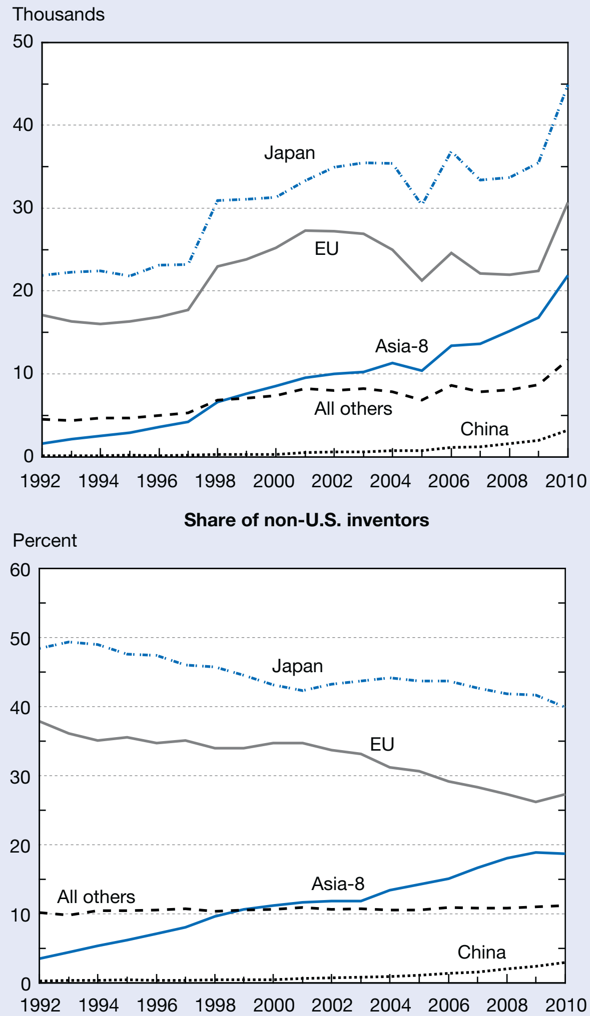
## New U.S. Patent Law

The America Invents Act, Public Law 112-29, 125 Stat. 283, signed into law on September 16, 2011, is the most significant reform of U.S. patent law since 1952. The act aims to foster innovation and improve productivity by making the U.S. patent system more compatible with the systems in other countries. Supporters of the act believe it will reduce a growing backlog of U.S. patent applications, reverse a decline in U.S. patent quality, decrease the number of patents for frivolous inventions, and diminish the amount of expensive and time-consuming patent litigation. Economists and legal scholars who have studied the U.S. patent system have advocated reforms such as those in the new law (see Jaffe and Lerner [2006] and Burk and Lemley [2011])

The America Invents Act has three major provisions:

- ♦ **First-to-file system.** The law changes the primary standard for granting U.S. patent applications from the longstanding "first to invent" doctrine to "first to file." Under the new law, patents would go to the inventor that files an application first, and disputes about who was first to invent would be avoided. The goals of this provision are to harmonize the U.S. patenting system with most other national patent offices and to reduce litigation over disputes about when a product or idea was invented.
- ♦ **Postgrant review.** The law establishes an administrative postgrant review process similar to opposition proceedings in European patent offices. The process allows a third party to challenge the validity of a patent within 9 months of the patent's issuance. The aims of this provision are to provide an alternative to litigation, improve the quality of patents, and generate better decisions about alleged patent infringements.
- ♦ **Budget and operations of the U.S. Patent and Trademark Office.** The law gives the U.S. Patent and Trademark Office (USPTO) authority to set its own fees, which had previously been set by Congress. The purpose of this provision is to give USPTO greater budget autonomy and allow it to reduce its application backlog by hiring more examiners and modernizing its IT systems when the need arises.

Figure 6-40
**USPTO patents granted to non-U.S. inventors, by selected region/country/economy: 1992–2010**




EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Technologies classified by The Patent Board™. Patent grants fractionally allocated among regions/countries on basis of proportion of residences of all named inventors. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU includes current member countries.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2011). See appendix tables 6-45 and 6-62.

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Japan has the largest share of foreign patent grants by the USPTO, 40%, down slightly from the early 2000s (figure 6-40 and appendix table 6-45). The EU is second, with a 27% share, a decline of 6 percentage points from 2000. The Asia-8 group was in third place with 20%; its share nearly doubled from 2000 to 2010, largely because of rapid growth by South Korea and Taiwan. Chinese patenting activities in the U.S. remained insubstantial, as did those of Brazil, Russia, and India, in contrast to much higher activity of Chinese and other national patent offices (see sidebar, "Trends in Patents Granted in China, India, and Russia").

### *USPTO Patenting Activity by U.S. Companies*

Patenting by U.S. industry provides an indication of inventive activity, mediated by the relative importance in different industries of patenting as a business strategy.

## Trends in Patents Granted in China, India, and Russia

The number of Chinese patent grants grew exponentially during the 2000s. Chinese patents granted to domestic residents rose more than 10-fold from 6,000 in 2002 to 65,000 in 2009 (table 6-C). During this period, the Chinese inventor share of Chinese patent grants increased from 28% to slightly more than 50%, suggesting that patent protection is becoming increasingly important for Chinese companies that sell to the large and growing Chinese consumer market. The bulk of applications by Chinese inventors have been in utility model and industrial designs, which are quicker, cheaper, and have a lower standard than invention patents. Observers have criticized Chinese utility and industrial design patents as low quality but innovation economists note that these types of patents have played an important role in fostering indigenous innovation in Japan, South Korea, and Taiwan.* Chinese patents granted to nonresident inventors have also risen rapidly, coinciding with the growing sales and interest of U.S. and other companies in the Chinese domestic market. The growth of patent grants by residents and nonresidents may also reflect the strengthening of China's patent protection during the 2000s (Zhao 2010).

India and Russia show divergent trends in patenting activity by domestic and foreign inventors. A minority of India's patents are granted to domestic investors, with their share falling from 40% in 2002 to 25% in 2006 (table 6-C). The rising share of patents granted to non-Indian inventors may reflect the strengthening of patent protection for pharmaceuticals and other goods by the Indian patent system during this period. Russian-based inventors dominate patents granted by their country with a share of 76%. This may reflect the orientation of many Russian companies to the domestic market.

*See Ernst (2011) for a discussion on Chinese patenting.

Table 6-C
**Patents granted by Brazil, China, India, and Russia, by share of resident and nonresident inventors: Selected years, 1995–2009**
Share (percent)

| Country | 1995 | 1999 | 2001 | 2003 | 2005 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|
| Brazil | | | | | | | | |
| Resident | 19.7 | 13.2 | 19.1 | NA | 10.2 | NA | 9.5 | NA |
| Nonresident | 80.3 | 86.8 | 80.9 | NA | 89.8 | NA | 90.5 | NA |
| Patents (number) | 2,659 | 3,219 | 3,589 | NA | 2,439 | NA | 2,451 | NA |
| China | | | | | | | | |
| Resident | 45.1 | 40.6 | 33.1 | 30.7 | 38.8 | 47.0 | 49.7 | 50.9 |
| Nonresident | 54.9 | 59.4 | 66.9 | 69.3 | 61.2 | 53.0 | 50.3 | 49.1 |
| Patents (number) | 3,393 | 7,637 | 16,296 | 37,154 | 53,305 | 67,948 | 93,706 | 128,489 |
| India | | | | | | | | |
| Resident | 25.7 | 29.3 | 34.2 | 40.3 | 32.3 | NA | NA | NA |
| Nonresident | 74.3 | 70.7 | 65.8 | 59.7 | 67.7 | NA | NA | NA |
| Patents (number) | 1,613 | 2,160 | 1,549 | 1,526 | 4,320 | 15,318 | 18,230 | NA |
| Russia | | | | | | | | |
| Resident | 81.4 | 78.7 | 84.6 | 83.3 | 83.1 | 80.0 | 77.3 | 75.5 |
| Nonresident | 18.6 | 21.3 | 15.4 | 16.7 | 16.9 | 20.0 | 22.7 | 24.5 |
| Patents (number) | 25,633 | 19,508 | 16,292 | 24,758 | 23,390 | 23,028 | 28,808 | 34,824 |

NA = not available

NOTES: Country of origin is based on first named applicant. Year of patent is based on date of patent grant.

SOURCE: World Intelllectual Property Organization, Intellectual Property Statistics, Patent grants by patent office by resident and nonresident, http://www.wipo.int/ipstats/en/statistics/patents/, accessed 15 June 2011.

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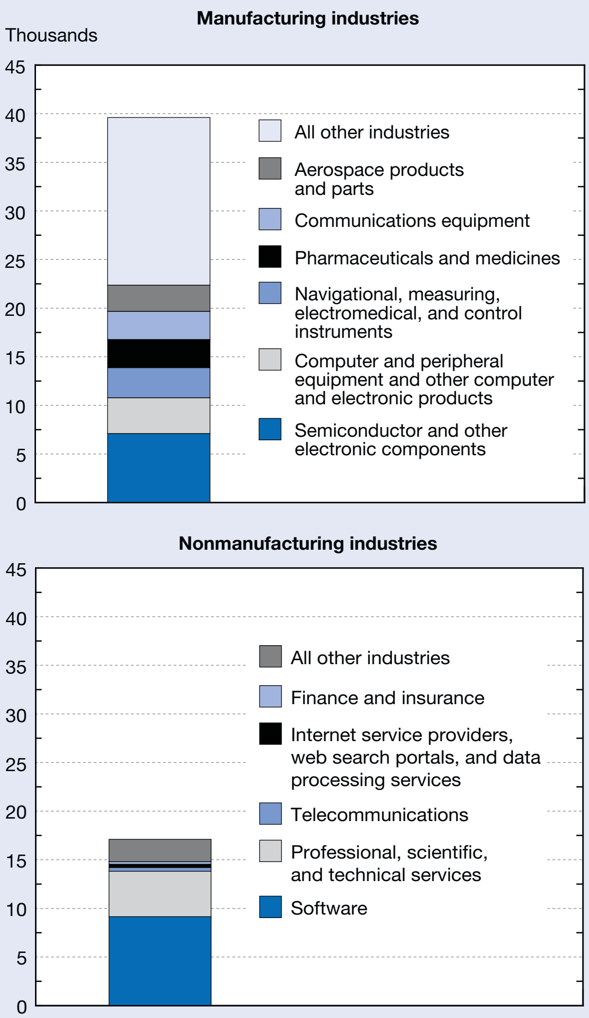
According to the NSF BRDIS survey, U.S. KTI industries account for a large share of USPTO patent grants (figure 6-41 and appendix table 6-46). U.S. HT industries were granted 23,000 patents, 57% of the 40,000 patents granted to all U.S. manufacturing industries in 2009. The U.S. semiconductor industry was issued the largest number of patents (7,000) among these HT industries, followed by 3,000 to 4,000 each for aerospace, computers, communications equipment, pharmaceuticals, and scientific and measuring equipment.

U.S. commercial KI services received 86% of the 17,000 patents issued to nonmanufacturing industries (figure 6-41 and appendix table 6-46). The software industry accounted for 9,000 patents, more than half of the patents issued to commercial KI services; professional and technical services were ranked second with 5,000 patents. Two industries in professional and technical services—scientific research and development services and computer systems design—reported significant patenting activity.

Figure 6-41
**USPTO patents granted, by selected U.S. industry: 2009**




NOTES: Detail may not add to total because of rounding. Industry classification based on dominant business code for domestic R&D performance where available. For companies that did not report business codes, classification used for sampling was assigned. Companies with fewer than five domestic employees not included.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey, 2008. See appendix table 6-46.

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## USPTO Patents Granted, by Technology Area

This section discusses trends in several technology areas in a new technology classification system that includes broad science and technologically advanced areas that are emerging and technologies closely aligned with HT industries. The largest area is ICT, which consists of networking, information processes, telecommunications, semiconductors, and computer systems (table 6-8 and appendix tables 6-45 and 6-47). It accounts for nearly 40% of all USPTO patents. Health-related technologies consist of biotechnology, pharmaceuticals, medical electronics, and medical equipment. A third broad area includes automation, control, and measuring technologies.

Several of these advanced and emerging technologies were among the fastest growing patent areas during the 2000s (table 6-8). Patents in networking grew at a nearly 20% average annual pace over the decade, information processes grew by 13%, and telecommunications and automation and control grew by 9%, compared to a 3% growth in total patents granted (appendix tables 6-45, 6-48, 6-49, 6-50, and 6-51). Other fast-growing technologies were medical electronics, semiconductors, optics, and measurement techniques and instrumentation (appendix tables 6-52, 6-53, 6-54, and 6-55).

Technologies that lagged behind overall growth in patents included pharmaceuticals, materials, and aerospace and defense (table 6-9 and appendix tables 6-56, 6-57, and 6-58). Weak activity in pharmaceuticals coincides with consolidation of the pharmaceutical industry in the last several years, stronger price and safety regulation of drugs in many developed countries, increased competition from generics, and little growth in Food and Drug Administration approval of new drugs (figure 6-42).

The next section will present patent technology activity indexes for selected regions/countries/economies, which measure the world share of a region, country, or economy in patents in a particular technology relative to its world share in all patents. A ratio greater than 1 signifies that patents by a region/country/economy are concentrated in a particular technology.

**ICT: Computer Systems, Information Processes, Networking, Semiconductors, and Telecommunications.** U.S. patents are concentrated in three ICT-related technologies: information processes, networking, and telecommunications, with special strength in information processes and networking (table 6-9 and appendix tables 6-45, 6-48, 6-49, and 6-50). U.S. patenting activity, however, is comparatively weak in semiconductors (appendix table 6-53).

EU patenting activity in ICT is comparatively low (table 6-9 and appendix tables 6-45, 6-48, 6-49, 6-50, 6-53, and 6-59). Several studies suggest that the EU has lagged behind the United States in ICT technology, but the pattern may also reflect a preference of EU inventors to patent in the European Patent Office. The United Kingdom is an

Table 6-8
**USPTO patents granted, by selected technology area: Selected years, 2000–10**

| Technology area | 2000 | 2003 | 2005 | 2007 | 2009 | 2010 | Average annual change: 2000–10 (%) |
|---|---|---|---|---|---|---|---|
| All technologies | 157,489 | 169,020 | 143,805 | 157,282 | 167,350 | 219,642 | 3.4 |
| Networking | 1,785 | 2,626 | 3,321 | 4,859 | 6,921 | 9,861 | 18.6 |
| Information processing | 6,539 | 7,533 | 8,141 | 11,672 | 15,075 | 22,038 | 12.9 |
| Automation and control | 1,591 | 1,843 | 1,856 | 2,773 | 3,225 | 3,951 | 9.5 |
| Telecommunications | 6,526 | 7,385 | 7,125 | 10,264 | 11,138 | 14,727 | 8.5 |
| Medical electronics | 2,066 | 2,575 | 2,026 | 2,439 | 2,565 | 3,489 | 5.4 |
| Semiconductors | 10,856 | 13,108 | 11,036 | 11,440 | 11,974 | 16,665 | 4.4 |
| Optics | 4,550 | 6,417 | 6,696 | 6,597 | 6,683 | 6,875 | 4.2 |
| Measurement techniques and instrumentation | 7,391 | 9,219 | 8,406 | 9,478 | 9,790 | 10,918 | 4.0 |
| Biotechnology | 5,606 | 5,379 | 4,117 | 5,940 | 5,826 | 8,206 | 3.9 |
| Computer systems | 8,848 | 9,789 | 9,711 | 10,506 | 11,680 | 12,654 | 3.6 |
| Aerospace and defense | 1,702 | 2,110 | 1,781 | 1,434 | 1,679 | 2,098 | 2.1 |
| Medical equipment | 6,929 | 7,412 | 4,913 | 4,582 | 4,691 | 7,424 | 0.7 |
| Pharmaceuticals | 5,388 | 5,590 | 3,911 | 3,835 | 4,275 | 5,471 | 0.2 |
| Materials | 5,580 | 5,793 | 4,006 | 3,658 | 3,582 | 5,193 | –0.7 |

USPTO = U.S. Patent and Trademark Office

NOTE: Technologies classified by The Patent Board™.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2011). See appendix tables 6-48–6-61.

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Table 6-9
**Activity in USPTO patent grants in selected technology areas, by selected region/country/economy: 2007–10 average**

| | Activity index | | | | | | |
|---|---|---|---|---|---|---|---|
| Technology area | United States | EU | Japan | South Korea | Taiwan | China | India |
| All ICT | 1.09 | 0.73 | 0.90 | 1.38 | 1.02 | 0.95 | 1.60 |
| Computer systems | 0.99 | 0.53 | 1.22 | 1.66 | 1.15 | 1.01 | 1.48 |
| Information processes | 1.31 | 0.75 | 0.66 | 0.43 | 0.37 | 1.01 | 2.35 |
| Networking | 1.31 | 0.80 | 0.50 | 0.68 | 0.38 | 1.03 | 2.30 |
| Semiconductors | 0.83 | 0.59 | 1.28 | 2.47 | 2.08 | 0.60 | 0.69 |
| Telecommunications | 1.03 | 1.03 | 0.73 | 1.59 | 0.94 | 1.12 | 1.31 |
| Automation and control | 1.10 | 0.94 | 0.85 | 0.72 | 1.17 | 1.39 | 0.92 |
| Measuring and instrumentation | 1.01 | 1.25 | 0.94 | 0.56 | 0.63 | 1.05 | 0.78 |
| Optics | 0.65 | 0.72 | 1.74 | 2.33 | 1.52 | 0.64 | 0.12 |
| Biotechnology | 1.23 | 1.28 | 0.42 | 0.35 | 0.29 | 0.86 | 1.57 |
| Pharmaceuticals | 1.03 | 1.95 | 0.45 | 0.26 | 0.20 | 0.75 | 4.64 |
| Medical electronics | 1.26 | 1.18 | 0.62 | 0.18 | 0.11 | 0.57 | 0.55 |
| Medical equipment | 1.40 | 1.03 | 0.33 | 0.14 | 0.39 | 0.38 | 0.18 |
| Aerospace and defense | 1.30 | 1.60 | 0.19 | 0.10 | 0.26 | 0.15 | 0.50 |
| Materials | 0.81 | 1.45 | 1.32 | 0.82 | 0.39 | 0.80 | 1.63 |

EU = European Union; ICT = information and communications technology; USPTO = U.S. Patent and Trademark Office

NOTES: Activity index consists of ratio of region/country/economy's share of indicated technology to region/country/economy's share of total grants. A ratio of greater than one signifies more active patenting in the selected technology; a ratio of less than one signifies less active patenting. Technologies classified by The Patent Board™. Patent grants fractionally allocated among regions/countries/economies on basis of proportion of residences of all named inventors. China includes Hong Kong.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2011). See appendix tables 6-47–6-56 and 6-58–6-61.

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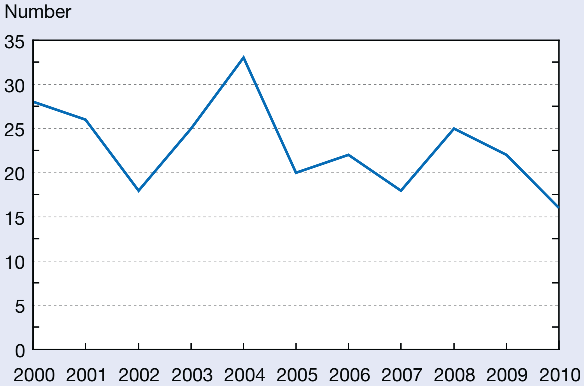
Figure 6-42
**New drugs approved by the FDA: 2000–10**




FDA = U.S. Food and Drug Administration

NOTE: New drugs consist of FDA-approved new molecular entities, ester, salt, or other noncovalent derivatives.

SOURCE: U.S. Food and Drug Administration, Drugs@FDA, http://www.accessdata.fda.gov/scripts/cder/drugsatfda/index.cfm?fuseaction=Reports.ReportsMenu, accessed 15 May 2011.

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exception in the EU with stronger activity in networking, telecommunications, and information processes, similar to the United States.

In Asia, Japan, South Korea, and Taiwan have similar ICT patterns, with strength in computer systems and semiconductors balanced by weaker activity in networking and information processes (table 6-9 and appendix tables 6-45, 6-48, 6-49, 6-50, 6-53, and 6-59). China has an uneven pattern in ICT technologies, with relative strength in telecommunications but average or low activity in other ICT areas. In a pattern that is consistent with an emphasis on developing ICT service industries, India scores high in all ICT areas but semiconductors.

**Biotechnology, Medical Electronics, Medical Equipment, and Pharmaceuticals.** The United States and the EU have relatively strong patenting activity in these health-related technologies (table 6-9 and appendix tables 6-45, 6-52, 6-56, 6-60, and 6-61). The United States is much weaker in pharmaceuticals, where the EU excels, and stronger in medical equipment.

Four of the Asian economies are very weak in these biomedical technologies (table 6-9 and appendix tables 6-45, 6-52, 6-56, 6-60, and 6-61). The exception is India, which has very strong activity in pharmaceuticals and biotechnology that coincides with its market presence in these industries.

**Automation and Control, Measuring and Instrumentation, and Optics.** These are areas of generally low patent activity. Relative strengths are automation and control for the United States, measuring techniques and instrumentation for the EU, and optics for Japan, South Korea, and Taiwan (table 6-9, and appendix tables 6-45, 6-51, 6-54, and 6-55). China's relative strength is in automation and control.

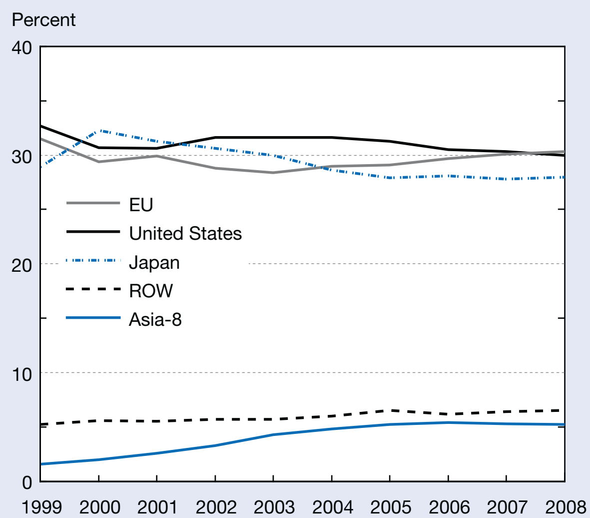
**Aerospace and Defense and Materials.** The United States and EU have a strong concentration in aerospace and defense, to which the EU adds strength in materials (table 6-9 and appendix tables 6-45, 6-57, and 6-58). This is also a strength for Japan, but the other Asian economies have comparatively low activity levels in these areas.

## Patenting Valuable Inventions: "Triadic" Patents

Using patent counts as an indicator of national inventive activity does not differentiate between inventions of minor and substantial economic potential. Inventions for which patent protection is sought in three of the world's largest markets—the United States, the EU, and Japan—are likely to be viewed by their owners as justifying the high costs of filing and maintaining these patents in three markets. These "triadic patents" serve here as an indicator of higher value inventions.

The number of such "triadic" patents was estimated at about 48,000 in 2008 (the last year for which these data are available), up from 45,000 in 1999, and showing little growth after 2004 (figure 6-43 and appendix table 6-63). The United States, the EU, and Japan held basically equal shares and their nearly identical positions in triadic patents contrast with the far greater gap between them in USPTO

Figure 6-43
**Global triadic patent families, by share of selected region/country/economy: 1999–2008**




EU = European Union; ROW = rest of world

NOTES: Triadic patent families include patents applied for in U.S. Patent and Trademark Office, European Patent Office, and Japan Patent Office. Patent families fractionally allocated among regions/countries/economies based on proportion of residences of all named inventors. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. EU includes current member countries.

SOURCE: Organisation for Economic Co-operation and Development, Patents Statistics, http://stats.oecd.org/WBOS/index.aspx, Patents by Region database, accessed 15 January 2011. See appendix table 6-63.

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patent grants.[29] The United States, the EU, and Japan together accounted for more than 93% of triadic patents in 1997, but that share dropped to 88% by 2008, largely reflecting a rapid rise in South Korean filings to 5% of the total.

## Trademark Applications

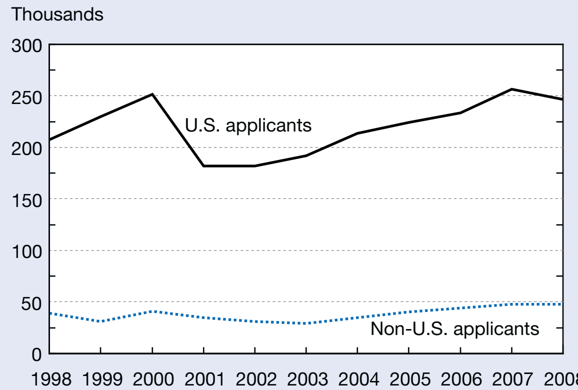
Firms use trademarks to launch new products and services, promote their brand, signal novelty, and appropriate the benefits of their innovation. Trademarks enable companies to establish exclusive identities for their new goods and services and to distinguish their products from those of competitors. Trademarks are considered a downstream indicator of innovation, showing the efforts of firms to build brand equity in new products and services. Because the U.S. market is large and open, this section will use applications for U.S trademarks as a measure of innovation activity for both the United States and other countries.

The total number of U.S. trademark applications was about 300,000 in 2008, with 250,000 applications originating from within the United States (figure 6-44 and appendix table 6-64). The EU, Canada, Switzerland, Japan, and China are the main sources of U.S. trademark applications from outside the United States (figure 6-45). The EU had the largest number of applications from abroad with 22,000, followed by Canada (6,500). Japan and China had the most activity among Asian economies with 3,200 and 2,500, respectively.

The number of U.S. trademark applications rose 20% from 1998 to 2008, although it dropped sharply during the recession of the early 2000s, and again showed signs of slowing during the late-decade recession (figure 6-44 and appendix table 6-64). The U.S. share has fluctuated between 83% and 88%. Among foreign applications, the EU share was consistently just below 50%, and Japan's share was approximately 7%–8% for the period (figure 6-45). China's share grew from 1% in 1998 to 5% in 2008. South Korea and India, although they have growing numbers of patent grants, have little trademark activity.

Patterns in trademark applications by class may indicate innovation activity in related technology or industry areas. Classes related to KTI industries are among those with the most applications in 2008. After advertising, the scientific and measuring category had the second-largest share of applications (10%) (figure 6-46). Several other classes—insurance and finance, science and technology, R&D and computer design, pharmaceuticals, and medical services—had shares of 2%–5% each.

Figure 6-44
**U.S. trademark applications by U.S. and non-U.S. applicants: 1998–2008**




SOURCE: World Intellectual Property Organisation, Statistics on Trademarks, http://www.wipo.int/ipstats/en/statistics/marks/, accessed 15 February 2011. See appendix table 6-64.

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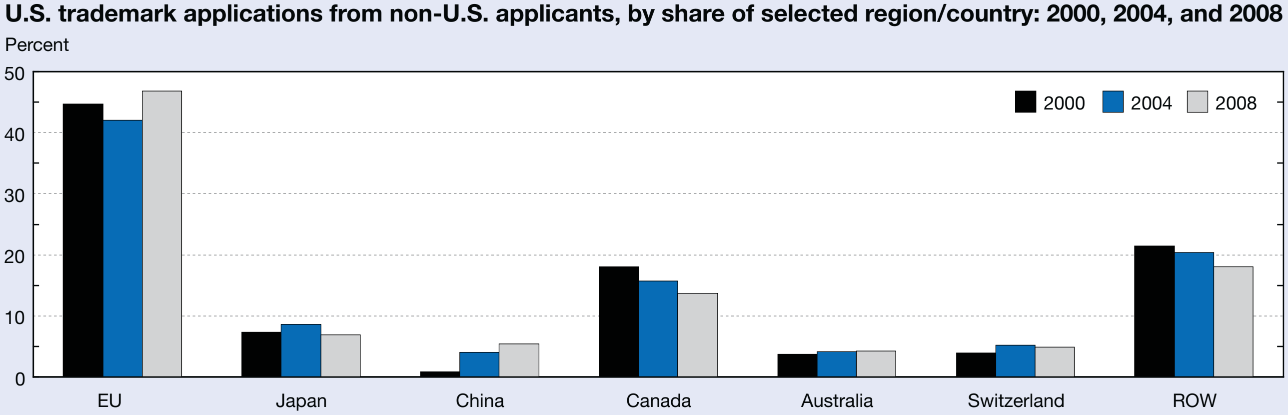
Figure 6-45
**U.S. trademark applications from non-U.S. applicants, by share of selected region/country: 2000, 2004, and 2008**




EU = European Union; ROW = rest of world

NOTES: EU includes current member countries. China includes Hong Kong.

SOURCE: World Intellectual Property Organisation, Statistics on Trademarks, http://www.wipo.int/ipstats/en/statistics/marks/, accessed 15 February 2011. See appendix table 6-64.

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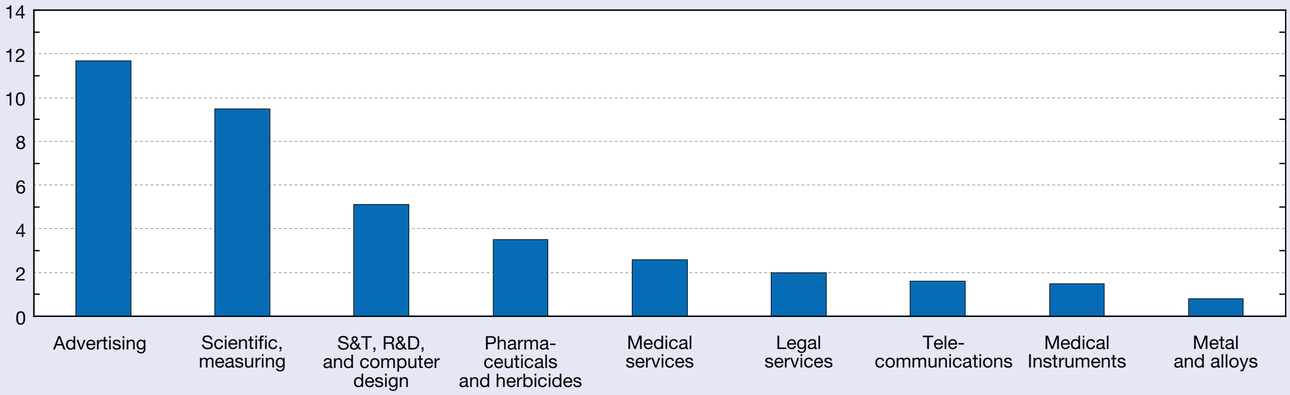
Figure 6-46
**Share of scientific and advanced-technology related classes of U.S. trademark applications: 2008**




S&T = science and technology

SOURCE: World Intellectual Property Organisation, Statistics on Trademarks, http://www.wipo.int/ipstats/en/statistics/marks/, accessed 15 February 2011.

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## U.S. High-Technology Small Businesses

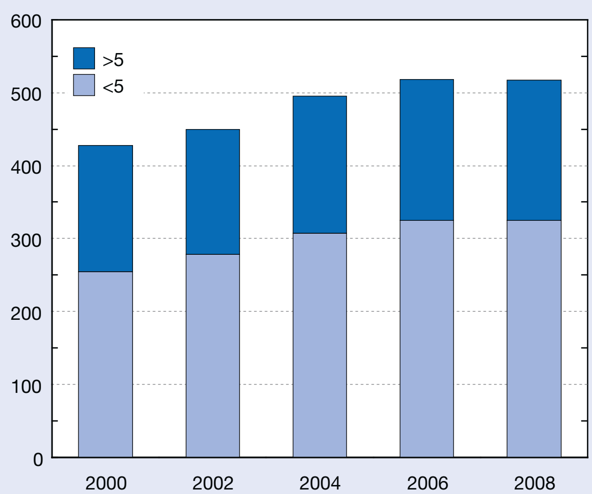
Many of the new technologies and industries seen as critical to U.S. innovation and economic growth are also identified with small businesses. Many large HT businesses invest in and acquire small businesses as part of their efforts to develop and commercialize new technologies. Biotechnology, the Internet, and computer software are examples of industries built around new technologies in whose initial commercialization microbusinesses—those with fewer than five employees—played an important role. Trends in the number of microbusinesses in emerging or established HT sectors may point to innovative industries with future areas of growth. This section covers patterns and trends that characterize microbusinesses operating in HT industries, based on data from the Census Bureau. Two sources of financing for HT small businesses—angel investment and venture capital investment—are also examined using data from the National Venture Capital Association and other sources.

### *Characteristics of Microbusinesses in U.S. High-Technology Industries*

According to U.S. Census data, the number of microbusinesses in industries classified as HT by the Bureau of Labor Statistics (BLS) is about 325,000, more than 60% of all firms operating in these industries (figure 6-47).[30] Services account for more than 90% (300,000) of U.S. HT microbusinesses, 20,000 operate in HT manufacturing, and 5,000 are in other industries. The proportion of services in non-HT microbusinesses is lower at 81%.[31]

The three HT services with the largest number of microbusinesses are management, scientific, and technical consulting; computer systems design; and architectural and engineering. HT manufacturing industries with large numbers of microfirms include navigational, measuring, and electromedical equipment and semiconductors (table 6-10).

Figure 6-47
**Number of U.S. high-technology firms, by size: Selected years, 2000–08**




NOTES: Firms with less than five employees include those reporting no employees on their payroll. Firm is an entity that is either a single location with no subsidiary or branches or topmost parent of a group of subsidiaries or branches. High-technology industries are defined by Bureau of Labor Statistics on basis of employment intensity of technology-oriented occupations. High-technology small business employment is lower bound estimate because employment not available for a few industries due to data suppression.

SOURCES: U.S. Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/econ/susb/, accessed 15 March 2011; Hecker DE. High-technology employment: A NAICS-based update, *Monthly Labor Review* 128(7):57–72 (2006), http://www. bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 15 March 2011.

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Table 6-10
**U.S. high-technology microbusinesses, by number of firms and employment for selected industries: 2008**

| | Firms | | Employment | |
|---|---|---|---|---|
| High-technology Industry | Number | Industry share of firms (%) | Employees | Industry share of employees (%) |
| All high-technology microbusinesses | 325,447 | 100.0 | 465,162 | 100.0 |
| All high-technology services | 300,487 | 92.3 | 420,099 | 90.3 |
| Management, scientific, and technical consulting services | 111,965 | 34.4 | 138,337 | 29.7 |
| Computer systems design and related services | 80,670 | 24.8 | 107,524 | 23.1 |
| Architectural, engineering, and related services | 62,234 | 19.1 | 99,932 | 21.5 |
| Professional and commercial equipment and supplies merchant wholesalers | 13,301 | 4.1 | 23,786 | 5.1 |
| Scientific research and development services | 7,088 | 2.2 | 11,001 | 2.4 |
| Data processing, hosting, and related services | 4,598 | 1.4 | 6,883 | 1.5 |
| Management of companies and enterprises | 3,392 | 1.0 | 4,365 | 0.9 |
| Software publishers | 2,310 | 0.7 | 3,977 | 0.9 |
| Wired telecommunications carriers | 1,521 | 0.5 | 2,477 | 0.5 |
| Wireless telecommunications carriers (except satellite) | 717 | 0.2 | 1,245 | 0.3 |
| Facilities support services | 642 | 0.2 | 1,030 | 0.2 |
| Satellite telecommunications | 388 | 0.1 | 583 | 0.1 |
| All high-technology manufacturing | 19,682 | 6.0 | 36,515 | 7.8 |
| Metalworking machinery manufacturing | 2,600 | 0.8 | 5,306 | 1.1 |
| Other fabricated metal product manufacturing | 2,032 | 0.6 | 3,759 | 0.8 |
| Navigational, measuring, electromedical, and control instruments manufacturing | 1,640 | 0.5 | 3,036 | 0.7 |
| Other general purpose machinery manufacturing | 1,602 | 0.5 | 3,044 | 0.7 |
| Motor vehicle parts manufacturing | 1,555 | 0.5 | 2,934 | 0.6 |
| Industrial machinery manufacturing | 1,118 | 0.3 | 2,189 | 0.5 |
| Semiconductor and other electronic component manufacturing | 1,098 | 0.3 | 1,982 | 0.4 |
| Electrical equipment manufacturing | 648 | 0.2 | 1,289 | 0.3 |
| Computer and peripheral equipment manufacturing | 495 | 0.2 | 804 | 0.2 |
| Pharmaceutical and medicine manufacturing | 466 | 0.1 | 848 | 0.2 |
| Communications equipment manufacturing | 382 | 0.1 | 659 | 0.1 |
| Aerospace product and parts manufacturing | 366 | 0.1 | 592 | 0.1 |
| Audio and video equipment manufacturing | 207 | 0.1 | 387 | 0.1 |
| Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing | 154 | 0.0 | 263 | 0.1 |
| All other industries | 5,278 | 1.6 | 8,548 | 1.8 |
| Oil and gas extraction | 4,545 | 1.4 | 7,433 | 1.6 |
| Electric power generation, transmission, and distribution | 342 | 0.1 | 547 | 0.1 |

NOTES: Microbusinesses are firms with fewer than five employees and include those reporting no employees on their payroll. Firm is an entity that is either a single location with no subsidiary or branches or topmost parent of a group of subsidiaries or branches. High-technology industries defined by Bureau of Labor Statistics on basis of employment intensity of technology-oriented occupations.

SOURCE: U.S. Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/econ/susb/, accessed 15 March 2011; and Hecker DE. High-technology employment: A NAICS-based update, *Monthly Labor Review* 128(7):57–72 (2006), http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 15 March 2011.

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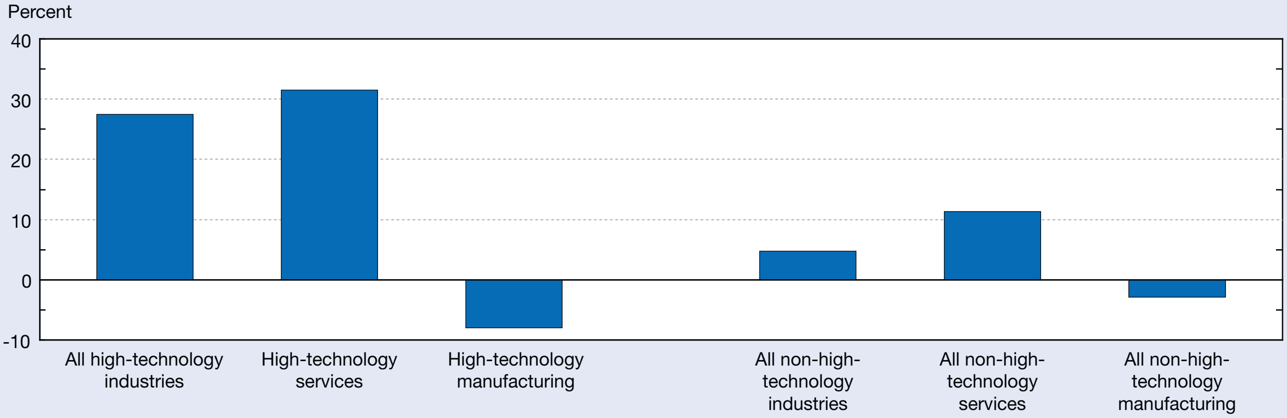
The number of microfirms in BLS-classified HT industries grew much faster than in other industries from 2000 to 2008 (figure 6-48). Growth of microfirms in services classified as HT was three times that in other service industries. However, the number of microfirms in manufacturing classified as HT had a deeper decline than in other manufacturing industries.

### *Financing of High-Technology Small Businesses*

Entrepreneurs seeking to start or expand a small firm with new or unproven technology may not have access to public or credit-oriented institutional funding. Often, they rely on friends and family for financing. However, when they need or can get access to larger amounts of financing, angel capital and venture capital investment are often critical to financing nascent and entrepreneurial HT businesses. (In this section, business denotes anything from an entrepreneur with an idea to a legally established operating company.)

Figure 6-48
**Growth in number of U.S. microbusinesses, by selected industry: 2000–08**




NOTES: Microbusinesses are firms with less than five employess and those reporting no employees on their payroll. Firm is an entity that is either a single location with no subsidiary or branches or topmost parent of a group of subsidiaries or branches. High-technology industries are defined by Bureau of Labor Statistics on basis of employment intensity of technology-oriented occupations. High-technology small business employment is lower bound estimate because employment not available for a few industries due to data suppression.

SOURCES: U.S. Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/econ/susb/, accessed 15 March 2011; Hecker DE, High-technology employment: A NAICS-based update, *Monthly Labor Review* 128(7):57–72 (2006), http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 15 March 2011.

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An angel investor is a person who provides capital, in the form of debt or equity, from his or her own funds to a private business owned and operated by someone else who is neither friend nor family (Shane 2008). Angel investors may invest on their own as individuals or through an informal network of affiliated investors. Angel funds are more formal organizations where groups of investors pool their resources and jointly invest in businesses.

Venture capitalists pool the investments of others (typically wealthy investors, investment banks, retirement funds, and other financial institutions) in a professionally managed fund. They receive ownership equity in the companies in which they invest, and they almost always participate in managerial decisions.

Angel and venture capital investment are generally categorized into four broad stages of financing:

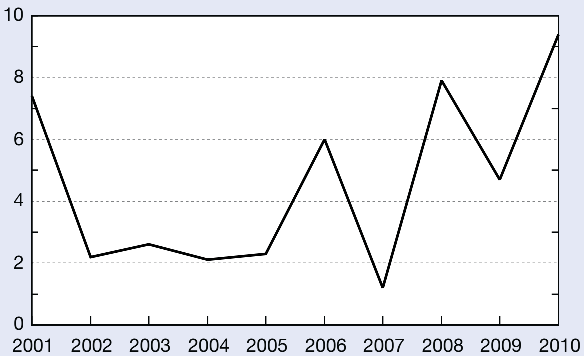
- **Seed and startup** supports proof-of-concept development (seed) and initial product development and marketing (startup or first round).
- **Early stage** supports the initiation of commercial manufacturing and sales.
- **Expansion** provides working capital for company expansion, funds for major growth (including plant expansion, marketing, or development of an improved product), and financing to prepare for an initial public offering (IPO).
- **Later stage** includes acquisition financing and management and leveraged buyouts. Acquisition financing provides resources for the purchase of another company, and a management and leveraged buyout provides funds to enable operating management to acquire a product line or business from either a public or a private company.

This section examines angel capital and venture capital investment patterns in the United States and internationally, focusing on the period from 2001 to 2008. The section examines (1) changes in the overall level of angel and venture capital investment, (2) venture capital investment outside the United States, (3) angel and venture capital investment by stage of financing, and (4) the technology areas that U.S. angel and venture capitalists find attractive.

**U.S. angel investment.** There are no sources of current, nationally representative data that directly measure U.S. angel investment. Data on U.S. angel investment have largely been restricted to samples that are not nationally representative or that rely disproportionately on angel groups and thereby exclude individual investors. This section will examine two data sources that provide some data on the level and activities of U.S. angel investment, the Global Entrepreneurship Monitor's (GEM's) survey of U.S. informal investment and the Angel Capital Association.

The GEM's U.S. survey is a nationally representative survey that provides a variety of data on patterns of U.S. entrepreneurship, including informal investment. The survey asks respondents who identify themselves as informal investors about their relationship with the person that received their investment, ranging from close family members to strangers. The proportion of strangers provides a crude estimate of the level of U.S. angel investment. By that measure, U.S. angel investment was estimated at $9 billion in 2010 (figure 6-49). Estimated U.S. angel investment has fluctuated widely between 2001 and 2010, from a low of $1 billion in 2007 to a high of $9 billion in 2010.

Figure 6-49
**Estimated U.S. angel investment: 2001–10**




NOTES: U.S. angel investment estimated from the Global Entrepreneurship Monitor's annual survey of the United States. Angel investment is estimated from the proportion of informal investors that lend to strangers multiplied by the average amount of investment per investor and the share of informal investors of the U.S. population of ages 18–99.

SOURCES: Global Entrepreneurship Monitor, http://www.gemconsortium.org/default.aspx; U.S. Census Bureau, Population Estimates, http://www.census.gov/popest/estbygeo.html, accessed 15 May 2011.

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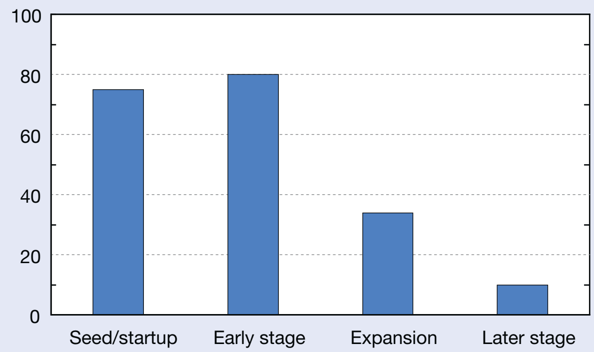
Figure 6-50
**Investment in financing stages preferred by Angel Capital Association member groups: 2009**




NOTES: Percent is share of Angel Capital Association member groups that express preferrence in investing in indicated investment stage. Seed and startup round supports proof-of-concept development (seed) and initial product development and marketing (startup). Early stage supports initiation of commercial manufacturing and sales. Expansion stage provides working capital for company expansion, funds for major growth (including plant expansion, marketing, or development of an improved product), and financing to prepare for an initial public offering. Later-stage funds include acquisition financing and management and leveraged buyouts.

SOURCE: Angel Capital Association Group, Investing through Angel Groups, http://www.angelcapitalassociation.org/, accessed 15 May 2011.

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The estimated level of angel investment is significantly lower than that of venture capital investment during this period, and anecdotal evidence suggests that HT areas receive a minority of U.S. angel investment. The returns to angel investors in lower technology industries can be very high, and many individual angel investors make limited or one-time investments, often in lower technology industries (Shane 2008).

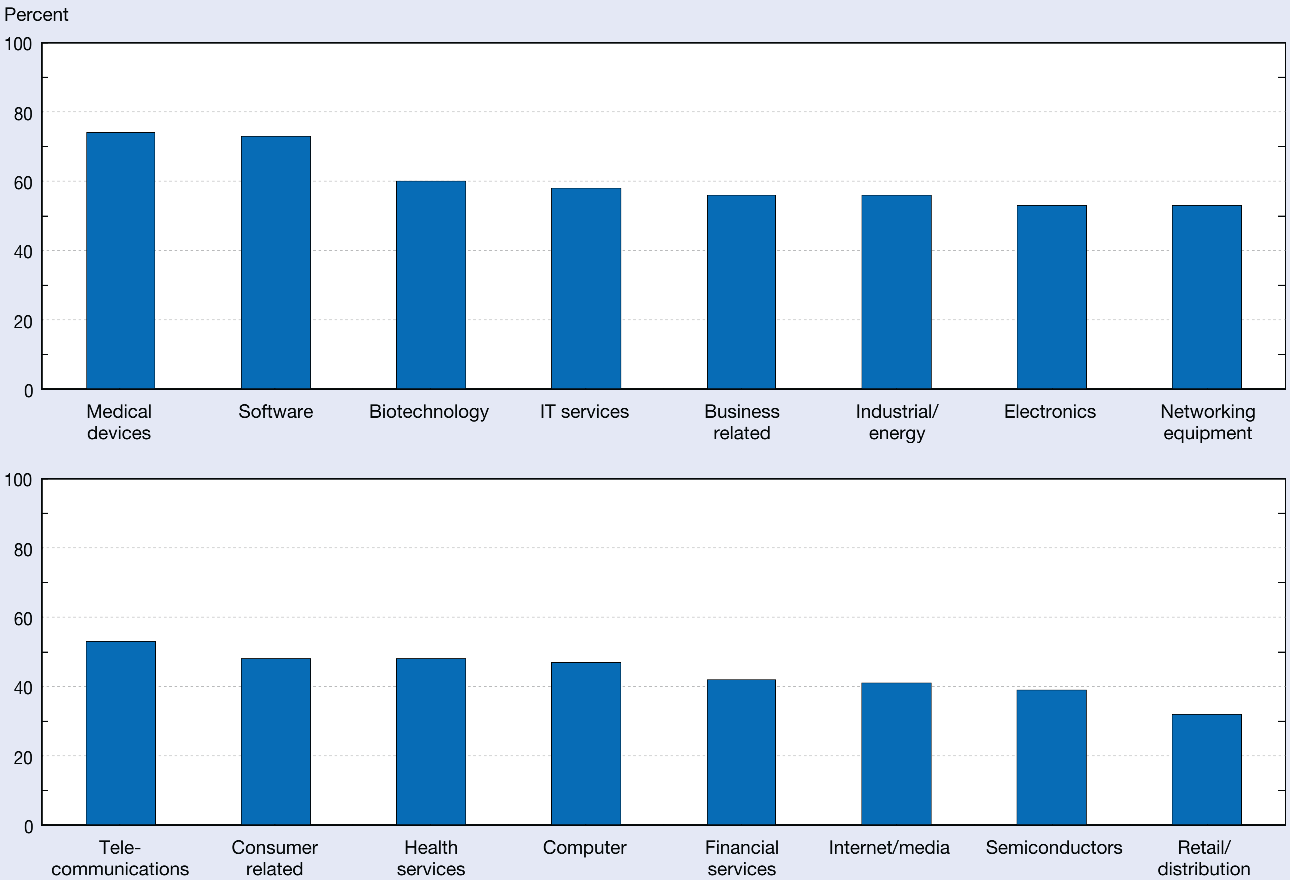
In contrast with individual angel investors, angel networks and groups are more likely to invest a larger share in HT industries. Angel groups allow angels to exchange and analyze information about industries and talk with experts on technologies. Angel groups that pool their investments can invest larger amounts that may be required for HT industries, such as biotechnology or medical devices.

The Angel Capital Association (ACA) is a trade association of 150 leading angel groups in North America. According to ACA's survey of its members, the average investment for an ACA group fell from $1.8–$1.9 million in 2007–08 to $1.4 million in 2009 during the recession. The majority prefer to invest in the earlier stages of financing of companies, with 70%–80% reporting preferences for seed/startup or early-stage financing (figure 6-50). Financing for the later stages of business operations—expansion and later stage—is far less preferred, with 33% preferring the expansion stage and only 10% preferring later stage financing. ACA members expressed strong interest in investing in HT industries (figure 6-51). Software and medical devices have the highest level of interest, with more than 70% of members showing interest, followed by biotechnology with 60%. Half or more of members expressed interest in investing in IT services, industrial/energy, telecommunications, and networking equipment.

**Venture capital investment.** Data from Dow Jones Venture Capital show that global venture capital investment rose more than 40% from $28 billion in 2005 to $41 billion in 2008 (figure 6-52). It fell sharply to $28 billion in 2009 in the midst of the recession. Investment rebounded in 2010 to reach $34 billion. The United States is the main source of venture capital financing, providing nearly 80% of global investment in 2010. U.S. venture capital investment grew 29%, from $24 billion to $31 billion, during this period. U.S. investment fell sharply in 2009 before growing modestly in 2010 to reach $26 billion. U.S. venture capital investment lagged behind the growth in non-U.S. investment between 2005 and 2010. As a result, the U.S. share of global venture capital investment fell from 85% to 78% during that period.

Venture capital investment originating outside the United States grew rapidly but from a low level, nearly doubling from $4 billion in 2005 to $7 billion in 2010 (figure 6-53). China led the growth in non-U.S. venture capital investment, with its investment tripling from $1.3 billion to $4 billion during the period from 2005 to 2010. China surpassed Europe in 2006 to become the largest source of non-U.S. investment, with its share reaching more than 50% in 2010. The remaining countries and regions—Canada, Europe, Israel, and India—provide small and relatively stable amounts of venture capital, with their shares of non-U.S venture capital investment ranging from 8% to 14%.

Figure 6-51
**Investment in technology areas preferred by member groups of the Angel Capital Association: 2009**




NOTE: Percent is share of Angel Capital Association member groups that express preferrence in indicated technology area.

SOURCE: Angel Capital Association Group, Investing through Angel Groups, http://www.angelcapitalassociation.org/, accessed 15 May 2011.

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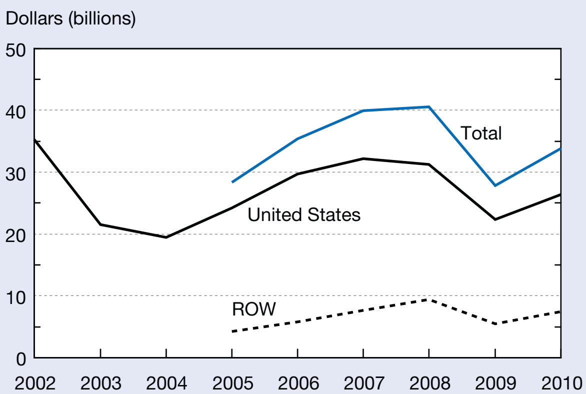
Figure 6-52
**Global and U.S. venture capital investment: 2002–10**




ROW = rest of world

NOTE: Data on non-U.S. venture capital investment not available for 2002–04.

SOURCE: Dow Jones, special tabulations (2011) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp. See appendix table 6-65.

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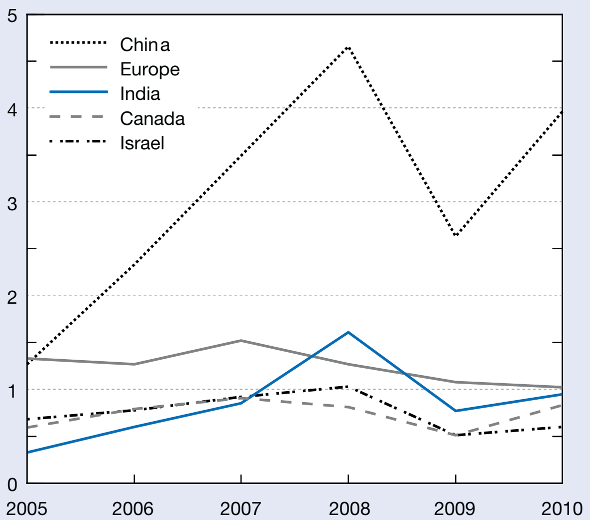
**U.S. venture capital investment by financing stage.** Knowledgeable observers believe that venture capital investment has become generally more conservative during the 2000s.[32] Later stage venture capital investment has both grown in absolute terms and as a share of total investment, from $10.8 billion (50% share of total investment) in 2002 to $17.4 billion (65% share) in 2010 (figure 6-54 and appendix table 6-65). The shift to later stage, more conservative investing has been attributed to a desire for lowered investment risk, higher minimum investment levels, which typically exceed earlier stages, a shorter time horizon for realizing gains, a decline in yields of venture capital investment, and the sharp decline in IPOs and acquisitions of venture capital-backed firms, which has required venture capital investors to provide additional rounds of financing.

In 2010, U.S. venture capital investment in the early stage, consisting of seed, startup, and initiation of commercial activities, was $4.6 billion, slightly higher than its level in 2002 but well below its prerecession peak of $7.9 billion in 2007 (figure 6-54 and appendix table 6-65). The early-stage share of total venture capital investment has declined steadily, from about 33% in the late 1990s to 20%–25% for much of the

Figure 6-53
**Non-U.S. venture capital investment, by region/country: 2005–10**




SOURCE: Dow Jones, special tabulations (2011) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp.

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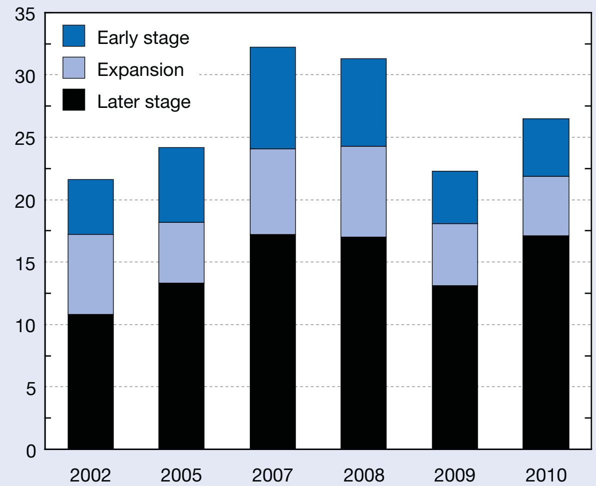
Figure 6-54
**U.S. venture capital investment, by financing stage: Selected years, 2002–10**




NOTES: Early stage consists of seed, startup, and initiation of commercial sales. Expansion consists of second round financing that provides working capital for company expansion, and financing to prepare for initial public offering. Later stage includes acquistion financing and management and leverage buyouts.

SOURCE: Dow Jones, special tabulations (2011) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp. See appendix table 6-65.

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2000s, and down to 17%–19% in 2009–10. The decline in early-stage investment both in absolute terms and as a share of total investment has amplified concerns that there is a growing lack of adequate financing for very young HT firms seeking to grow and successfully commercialize their technologies.

**U.S. venture capital financing by technology.** Five technologies—software, biopharmaceuticals, medical devices and equipment, consumer information services, and business support services—dominate venture capital financing (table 6-11 and appendix table 6-65). During 2007–10, these five technologies accounted for more than 60% of total and early-stage investment. Software and biopharmaceuticals received the most financing, with each receiving nearly $18 billion in total financing. Total and early-stage investment in software dropped sharply (33%–44%) between 2002 and 2010, reducing software's share of venture capital investment by half. Total investment in biopharmaceuticals remained roughly flat but early-stage financing dropped from $900 million to $600 million during this period.

Medical devices and equipment were second, receiving $13 billion in total financing (table 6-11 and appendix table 6-65). Total investment in this technology increased 27% from $1.8 billion in 2002 to $2.2 billion in 2010. Consumer information services and business support services were third, receiving $10–$11 billion. Consumer information services had the fastest growth among these five technologies, with total investment rising exponentially from less than $200 million in 2002 to $4.5 billion in 2010. Growth in early-stage financing was also rapid, rising from less than $50 million to $600 million. Total investment in business support services rose by 70% from $1.5 billion to $2.7 billion, and early-stage investment more than doubled from $200 million to $500 million.

## Investment and Innovation in Clean Energy and Technologies

Clean energy and energy-conservation and related technologies, including biofuels, solar, wind, nuclear, energy efficiency, pollution prevention, smart grid, and carbon sequestration, have become a policy focus in developed and developing nations. These technologies are knowledge and technology intensive and thus are closely linked to scientific R&D. Production, investment, and innovation in these energies and technologies are rapidly growing in many countries. Prompted by concerns over the high cost of fossil fuels and their impact on the climate, governments have directed both stimulus funding and long-term investments into these technologies. Private investors have also shown increased interest.

This section will examine public research, development, and demonstration (RD&D) data from the International Energy Agency (IEA) and venture capital and total private financing data from Bloomberg New Energy Finance, by technology and key region. A sidebar, "Government Stimulus Funding for Clean Energy," will summarize various countries' initiatives related to clean energy as part of their stimulus measures or long-range policies. The IEA data discussed here cover research, development, and

Table 6-11
**U.S. venture capital investment, by selected financing stage and industry/technology: Selected years, 2002–10**
(Millions of U.S. dollars)

| Technology/industry | 2002 | 2005 | 2007 | 2008 | 2009 | 2010 | 2007–10 total |
|---|---|---|---|---|---|---|---|
| | | | | All financing stages | | | |
| All technologies/industries | 21,509 | 24,207 | 32,200 | 31,243 | 22,348 | 26,415 | 112,206 |
| Software | 5,612 | 5,591 | 5,669 | 5,153 | 3,231 | 3,762 | 17,815 |
| Biopharmaceuticals | 3,243 | 4,074 | 5,822 | 4,626 | 4,030 | 3,246 | 17,725 |
| Medical devices and equipment | 1,776 | 2,361 | 3,791 | 3,615 | 2,959 | 2,249 | 12,614 |
| Consumer information services | 152 | 661 | 1,740 | 2,525 | 1,792 | 4,552 | 10,610 |
| Business support services | 1,471 | 1,719 | 2,989 | 2,808 | 2,120 | 2,516 | 10,433 |
| | | | | Early-stage financing | | | |
| All technologies/industries | 4,351 | 5,958 | 8,104 | 6,999 | 4,242 | 4,570 | 23,916 |
| Biopharmaceuticals | 932 | 1,139 | 1,601 | 1,345 | 854 | 578 | 4,378 |
| Software | 1,299 | 1,139 | 1,190 | 839 | 788 | 726 | 3,543 |
| Consumer information services | 43 | 340 | 878 | 870 | 382 | 623 | 2,753 |
| Business support services | 217 | 514 | 905 | 841 | 503 | 462 | 2,711 |
| Medical devices and equipment | 337 | 437 | 722 | 784 | 356 | 333 | 2,194 |

NOTES: Technologies classified by Dow Jones. Early-stage financing consists of seed, startup, and initiation of commercial sales.

SOURCE: Dow Jones, special tabulations (2011) of VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp. See appendix table 6-65.

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demonstration. They are not comparable to energy RD&D data described in Chapter 4, which focus on research and development.[33]

## Commercial Investment

According to Bloomberg New Energy Finance, global commercial investment in clean energy and technology from all sources, including early-stage angel and venture capital investment and later stage financing raised from private equity and public capital markets, has risen rapidly from less than an estimated $20 billion in 2004 to nearly $154 billion in 2010 (figure 6-55).[34] This rise has been spurred by government policies, financial incentives, and funding to foster the development of clean energy production and technologies; falling costs in wind and solar energy; and investor perception that this area is ready for large-scale commercialization. The United States, EU, China, and other countries provided additional support of nearly $200 billion to this sector from stimulus funding to help spur recovery from the global recession (see sidebar, "Government Stimulus Funding for Clean Energy").

The United States generated an estimated $30 billion (19% global share) in clean energy commercial investment in 2010, placing it behind China and roughly equal to the EU (figure 6-55). After peaking at $34 billion in 2008, U.S. commercial investment declined sharply to $20 billion in 2009 during the global financial crisis before recovering in 2010 to reach nearly its pre-crisis peak.

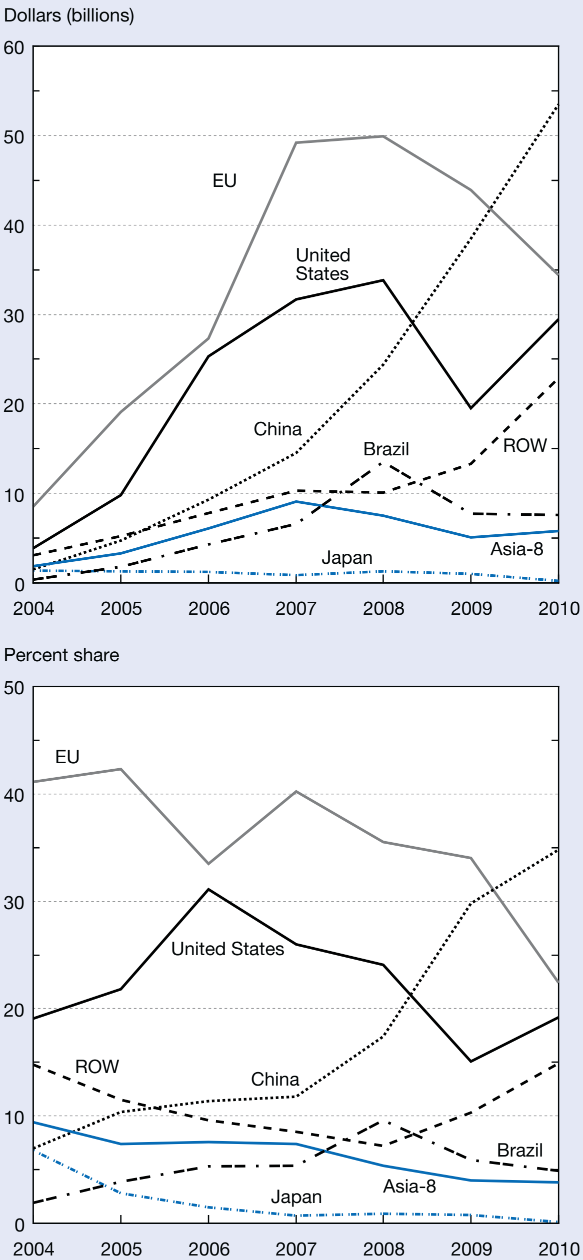
China provided an estimated $54 billion in clean energy financing in 2010, more than any economy in the world (35% share of global investment) (figure 6-55). China's commercial investment rose exponentially from less than $2 billion in 2004 to $54 billion in 2010, surpassing the United States in 2009 and the EU in 2010. The uninterrupted growth of clean energy investments in China reflects the government's commitment to reduce China's reliance on fossil fuels, considerable financing from state development banks (less affected by the financial crisis than other countries/regions), low labor costs, and subsidies to encourage large renewable energy projects, particularly in wind and solar energy.

The EU ties with the United States in clean energy investment, providing an estimated $34 billion in 2010 (22% share of global investment) (figure 6-55). Clean energy investment in the EU has been spurred by government policies such as feed-in tariffs for solar power in Germany and Spain and large-scale investment in offshore wind by the UK. However, EU clean energy investment dropped from $50 billion in 2008 to $23 billion in 2010, reflecting the global recession and sharp cutbacks by Spain, the UK, and other EU countries in their support of solar and other clean energies.

Brazil and the Asia-8 have comparatively low activity in clean energy financing (an estimated $8 and $6 billion, respectively) (figure 6-55). India provides the largest amount of financing ($3.8 billion) from the Asia-8. Investment from both Brazil and the Asia-8 grew rapidly from 2004 to 2010, though from a low base. Japan provided less than $1 billion in clean energy investment in 2010, down sharply from $7 billion in 2004.

Wind technology is the largest recipient of global clean energy financing, with an estimated $99 billion (65% share of total investment) in 2010 (figure 6-56). Wind energy accounted for nearly 60% of total clean energy investment by the EU and the United States and more than 80% by China in 2010 (table 6-12).

Figure 6-55
**Financial new investment in clean energy and technologies, by selected region/country/economy: 2004–10**




EU = European Union; ROW = rest of world

NOTES: Clean energy and technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency. Financial new investment includes private and public R&D, venture capital, private equity, and public markets. Mergers and acquisitions are excluded. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2011).

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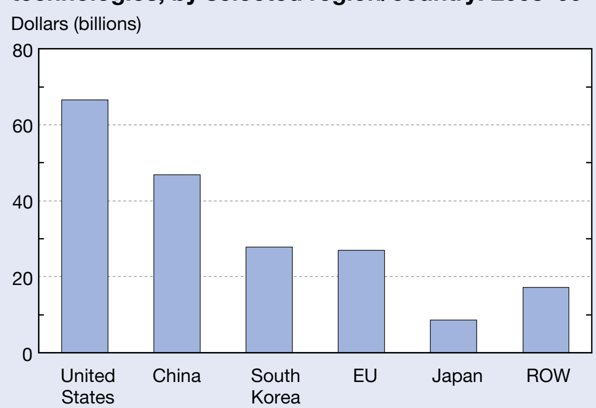
## Government Stimulus Funding for Clean Energy

A number of economies pledged an estimated $194 billion in late 2008 and early 2009 for clean energy and low carbon energy projects as part of their stimulus programs undertaken in response to the global economic recession (figure 6-D). Four of these economies, the United States, China, South Korea, and the EU, led stimulus funding of clean energy with a collective $168 billion in spending commitments. The United States had the largest amount with $67 billion in commitments for energy efficiency, renewable energy deployment, transportation, and smart grid technology. China announced $47 billion in funding for energy efficiency, clean vehicles, grid infrastructure, and other energy technologies. The EU and South Korea each committed $27–$28 billion in funding.

Progress was slow in 2009 with governments spending an estimated $20.3 billion (10%) of the total $194 billion in stimulus commitments. The pace accelerated in 2010 with 38% of the stimulus funding commitments (an estimated $74.5 billion) being spent, largely by the United States, China, Germany, and South Korea. Disbursement of stimulus spending commitments in 2009–10 is estimated at $94.8 billion. The majority of this funding has gone to energy efficiency, renewables, smart grid, and R&D. Energy efficiency has received an estimated $35.5 billion (37% share) followed by $20.2 billion (21%) allocated to renewables. R&D and the smart grid have each received $17–$18 billion.

Figure 6-D
**Public stimulus funding for clean energy and technologies, by selected region/country: 2008–09**




EU = European Union; ROW = rest of world

NOTE: Funding amounts are commitments announced by governments in 2008 and 2009.

SOURCE: Pew Charitable Trust, “Who’s winning the clean energy race,” http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/G-20Report-LOWRes-FINAL.pdf, accessed 15 May 2011.

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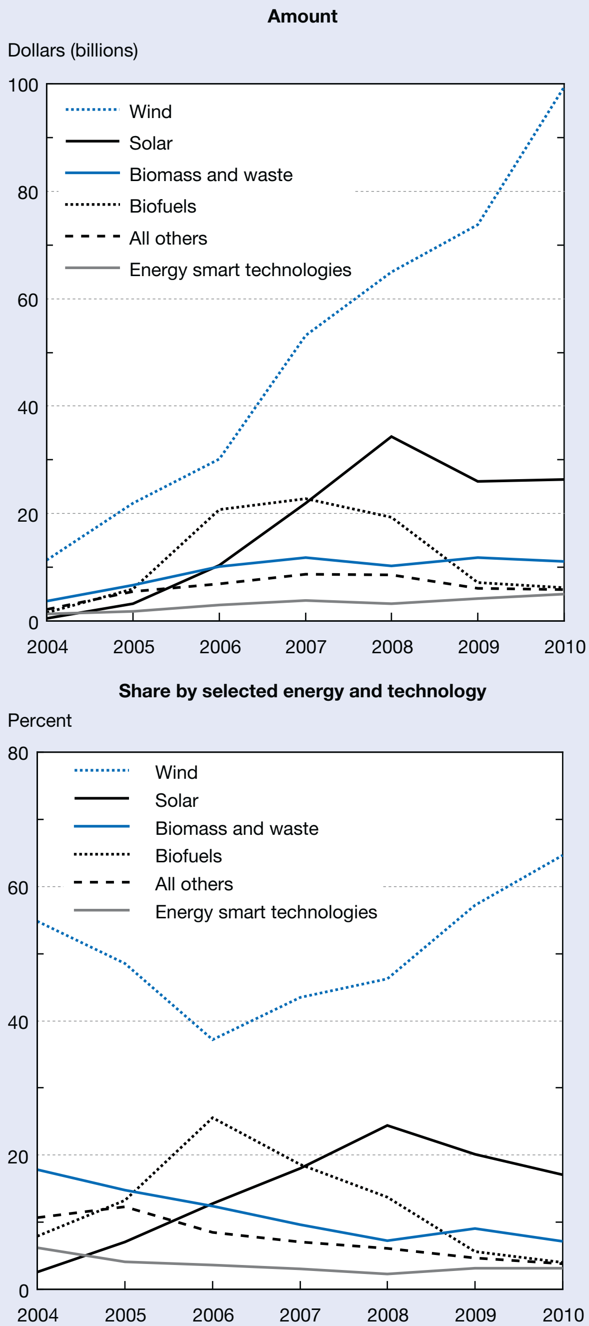
China is the world's largest source of investment in wind technology with an estimated $45 billion in 2010, more than twice as much as the EU ($19 billion) and the United States ($17 billion) (table 6-12). China's rapid growth in this field, from less than $1 billion in 2004 to $45 billion in 2010, was spurred by aggressive government policies and comparatively low labor and financing costs. Solar is the second-largest clean energy technology area with an estimated $26 billion of investment in 2010 (17% share of global investment) (figure 6-56). Commercial investment in solar grew rapidly from less than $1 billion in 2004 to a peak of $34 billion in 2008 before falling to $26 billion in 2009–10. The fall in investment may reflect volatility in the price of photovoltaic modules and, in the case of the EU, reductions in government support and incentives in Germany, Spain, and other EU countries. The EU is the world's largest source of financing for solar with an estimated $11 billion in 2010, down sharply from $22 billion in 2008. The marked decline in EU financing reflects the recession and cutbacks by Germany, Spain, and the United Kingdom in government support and incentives for solar power. The United States is the second-largest source of financing in solar with $6 billion in 2010, up from $4 billion in 2009 but below the peak of $8 billion in 2008. China is the third-largest source of solar investment with $4 billion. Chinese investment in this area was negligible in 2004–05 before rising to $2 billion in 2006 and doubling to $4 billion in 2010.

Figure 6-56
**Financial new investment in clean energy and technologies, by select energy and technology: 2004–10**




NOTES: Clean energy and technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency. Financial new investment includes private and public R&D, venture capital, private equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2011).

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Biomass/waste was the third-largest area of investment, with an estimated $11 billion in 2010 (figure 6-56). After rising rapidly from $4 billion to $10 billion from 2004 to 2006, investment leveled off at $10–11 billion from 2006 to 2010. Biofuels is the fourth-largest area of investment, with $6 billion in 2010. Investment in this sector is down sharply from its $23 billion peak in 2006 due to excess capacity and overinvestment, particularly in the U.S. ethanol sector; volatility in the price of oil; and falls in the prices of corn and other commodities used in biofuels production.[35] U.S. investment slid from $9 billion in 2006 to $1 billion in 2010, and EU investment also fell sharply (table 6-12).

## Venture Capital Investment

Venture capital investment is a useful indicator of market assessment of future technology trends. As an important source of financing for new firms, it may indicate nascent areas of clean energy technologies.

Data from Bloomberg New Energy Finance show that global venture capital investment in clean energy rose rapidly, more than quadrupling from an estimated $1 billion in 2004 to $4 billion in 2010, after a sharp recession-induced dip in 2009 (figure 6-57). The United States is the main provider of venture capital financing for clean energy technologies, with more than 90% of global investment in 2010. The EU, China, and other Asian economies have been negligible sources of venture capital.

Two major technology areas, energy smart/efficiency and solar, dominate global venture capital investments in clean energy, receiving an estimated $2 billion and $1.5 billion, respectively (figure 6-58). The energy smart/efficiency category covers a wide range of technologies from digital energy applications to efficient lighting, electric vehicles, and the

Table 6-12
**Financial new investment, by selected region/country and energy/technology: 2004–10**
(Millions of dollars)

| Region/country and technology | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|
| EU | | | | | | | |
| Wind | 6,728 | 12,034 | 12,413 | 25,316 | 22,546 | 20,660 | 19,243 |
| Solar | 319 | 1,809 | 5,359 | 13,718 | 22,200 | 15,222 | 11,491 |
| Biofuels | 477 | 1,510 | 4,450 | 4,694 | 1,994 | 1,726 | 167 |
| United States | | | | | | | |
| Wind | 1,574 | 3,962 | 9,210 | 11,167 | 17,593 | 10,479 | 17,142 |
| Solar | 153 | 1,124 | 2,389 | 5,514 | 7,834 | 3,666 | 5,580 |
| Biofuels | 989 | 2,651 | 10,448 | 9,136 | 4,078 | 935 | 1,155 |
| China | | | | | | | |
| Wind | 220 | 1,473 | 3,678 | 7,472 | 17,368 | 30,764 | 44,875 |
| Solar | 3 | 90 | 562 | 197 | 1,981 | 3,967 | 3,856 |
| Biofuels | 17 | 64 | 1,117 | 1,397 | 187 | 43 | NA |

EU = European Union; NA = not available

NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency. Financial new investment includes venture capital financing raised from private equity, and public capital markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2011).

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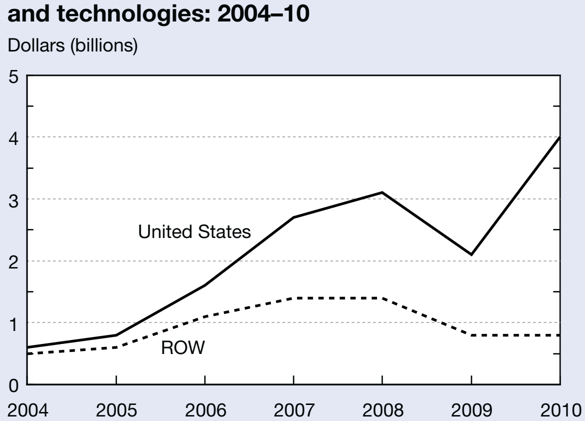
smart grid that maximizes the energy efficiency of existing energy sources and networks.

The attractiveness of these technologies may be enhanced by sizable public R&D funding. In addition, energy efficiency technologies are less capital intensive than other clean energy technologies, have a shorter time horizon than most other energy technologies, can be applied to a wider range of energy products and services, and are less reliant on government incentives or subsidies that may be withdrawn. This sector has also benefited from increased U.S. public research spending. Investor interest has been in electric cars and the smart grid, both of which have received U.S. stimulus funding.

Biofuels is the third-largest technology in terms of venture capital investment, with a share of 10% in 2010 (figure 6-58). Wind energy has received less than 5% of venture capital investment, far less than its dominant share in total commercial investment.

Figure 6-57
**Global venture capital investment in clean energy and technologies: 2004–10**




ROW = rest of world

NOTE: Clean energy and technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2011).

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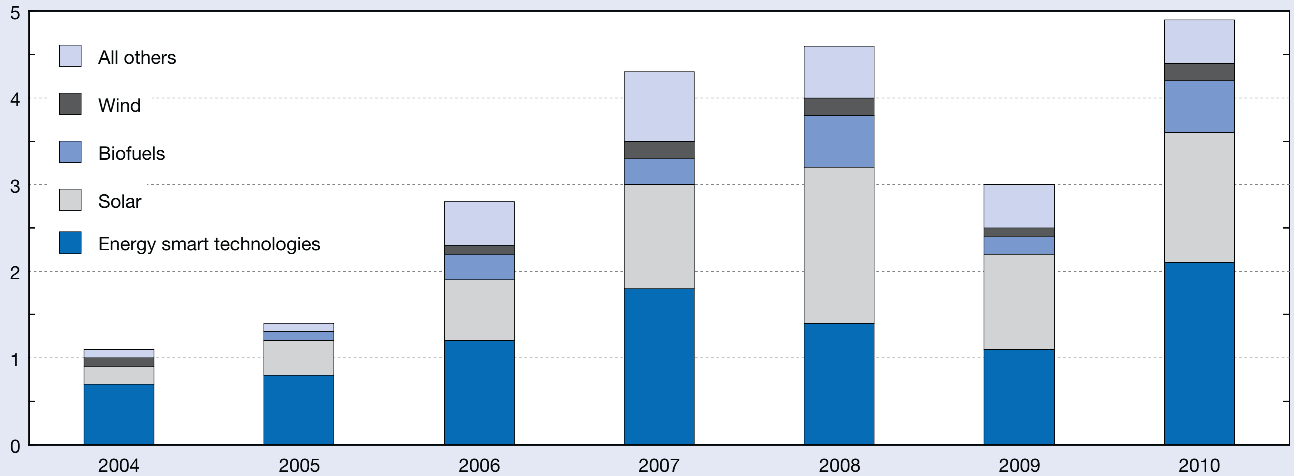
## Public Research, Development, and Demonstration Expenditures in Clean Energy and Technologies

According to IEA data, the estimated amount of global public R&D and demonstration (RD&D) investment for clean energy and related technologies was $16.7 billion in 2009 (figure 6-59). Clean energy RD&D includes solar, wind, ocean, nuclear, bioenergy, hydrogen, fuel cells, carbon capture and storage, and energy efficiency.[36]

Nuclear energy was the largest area, receiving $5.3 billion in 2009, one-third of total RD&D (figure 6-59). RD&D funding for nuclear energy has remained relatively flat during the 2000s. The next two largest areas are energy efficiency and renewable energy (solar, wind, ocean, bioenergy), which each received about $4 billion in public RD&D. Other power and storage was third, receiving $1.6 billion (figure 6-59). Renewable energy had the fastest growth between 2000 and 2009, more than quadrupling from $900 million to $3.9 billion. Growth was also rapid in hydrogen and fuel cells, which increased from $32 million in 2002 to $900 million in 2009.

The United States in 2009 had the largest investment in clean energy RD&D; its $7.0 billion accounted for 42% of global RD&D (figure 6-60). However, this figure included one-time funding from the American Recovery and

Figure 6-58
**Global venture capital investment in clean energy and technologies: 2004–10**




NOTE: Clean energy and technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2011).

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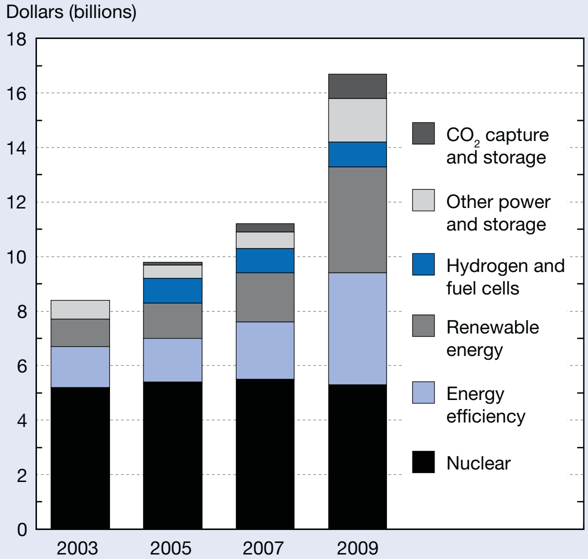
Figure 6-59
**Global government RD&D in clean energy and technologies, by technology area: 2003, 2005, 2007, and 2009**




EU = European Union; RD&D = Research, development, and demonstration

NOTES: RD&D includes research, development, and demonstration projects. Clean energy and technologies include solar, wind, bioenergy, nuclear, fuel cells, hydrogen, $CO_2$ capture and storage, other power and storage, and energy efficiency. EU consists of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovak Republic, Spain, Sweden, and United Kingdom. Data not available for China.

SOURCE: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 March 2011.

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Reinvestment Act (ARRA). For much of the 2000s, U.S. public investments had been the third largest behind the EU and Japan, which in 2009 invested about $4.0 billion each, nearly a quarter each of global RD&D.

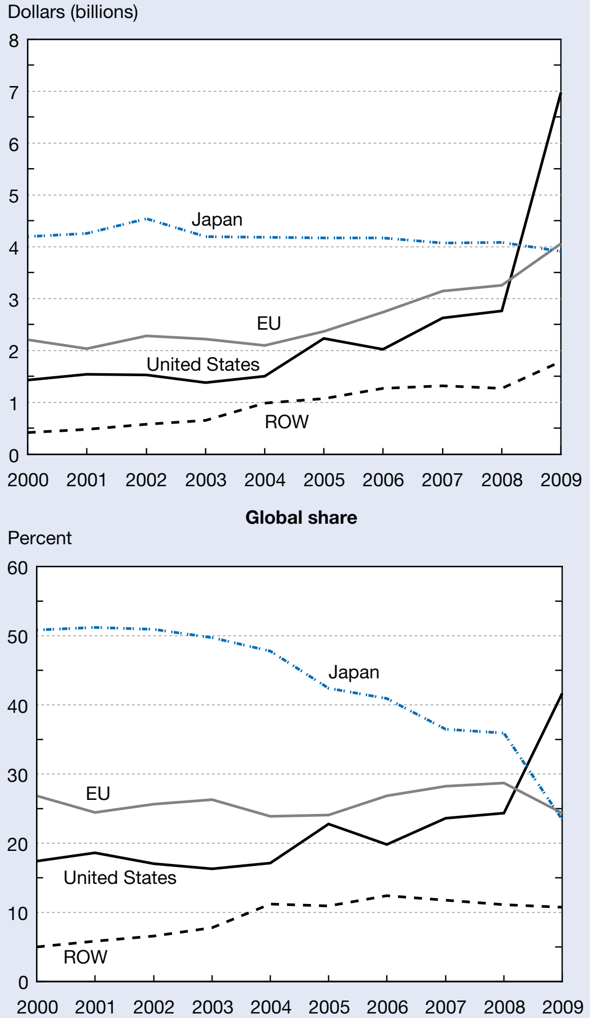
Global public RD&D investment more than doubled between 2000 and 2009 from $8.2 billion to $16.7 billion (figure 6-60). Increases in funding in the United States and the EU propelled growth after 2003; Japan's public RD&D expenditures stayed flat during this period. More recent U.S. data show a sharp decline in U.S. clean energy RD&D investment from $7.0 billion in 2009 to $4.4 billion in 2010, when ARRA funding declined (figure 6-61).

U.S. energy-related RD&D funding across technologies has been volatile (figure 6-62). Energy efficiency, including smart grid, and renewable energy were the two largest areas, each receiving about 30% of funding in 2010. In the renewable energy area, biofuels received the largest share of funding, followed by solar and smaller amounts for wind and ocean energy. The shares of energy efficiency and renewable energy jumped starting in 2009 because most ARRA funding was allocated to these two areas. Nuclear is the third-largest area, receiving 20% of expenditures. Nuclear had been the largest area for much of the 2000s but received scant funding from ARRA, resulting in its share falling from 36% in 2008 to 20% in 2010.

## Patenting of Clean Energy and Pollution Control Technologies

USPTO patents granted in clean energy and pollution control technologies can be classified using a new taxonomy developed for this purpose. The taxonomy classifies patents involving bioenergy, nuclear, wind, solar, energy storage, smart grid, and pollution mitigation. The number of patents in these technologies jumped to a record high in 2010, which may mostly reflect USPTO efforts to speed up processing of applications (figure 6-63 and appendix table 6-66).[37] (For a more detailed description of how this taxonomy identifies clean energy and pollution control patents, see the section in Chapter 5, "Identifying clean energy and pollution control patents.") U.S. resident inventors

Figure 6-60
**Government RD&D expenditures for clean energy and technologies, by selected region/country: 2000–09**




EU = European Union; RD&D = Research, development, and demonstration; ROW = rest of world

NOTES: RD&D includes research, development, and demonstration projects.Clean energy and technologies includes solar, wind, bioenergy, nuclear, fuel cells, hydrogen, $CO_2$ capture and storage, other power and storage, and energy efficiency. EU includes Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and United Kingdom. ROW includes Australia, Canada, and South Korea. Data not available for China.

SOURCE: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 April 2011.

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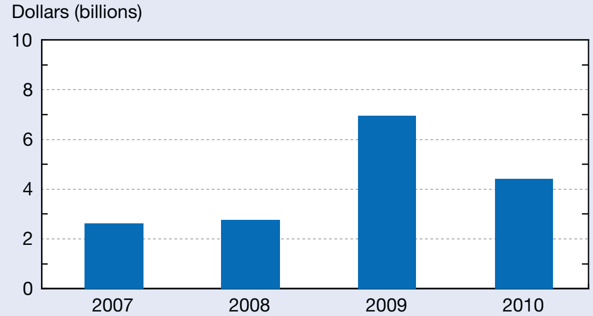
Figure 6-61
**U.S. government RD&D expenditures on clean energy and technologies: 2007–10**




ARRA = American Recovery and Reinvestment Act of 2009; RD&D = Research, development, and demonstration

NOTES: RD&D includes research, development, and demonstration projects. Clean energy and technologies includes solar, wind, bioenergy, nuclear, fuel cells, hydrogen, $CO_2$ capture and storage, other power and storage, and energy efficiency.

SOURCE: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 March 2011.

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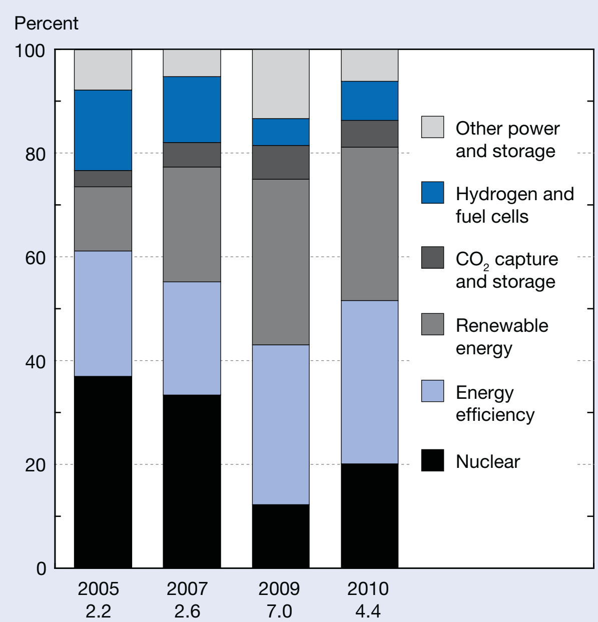
Figure 6-62
**U.S. government RD&D in clean energy and technologies, by share of technology area: 2005, 2007, 2009, and 2010**




ARRA = American Recovery and Reinvestment Act of 2009; RD&D = Research, development, and demonstration

NOTES: RD&D includes research, development, and demonstration projects. Amount of R&DD shown in billions of current dollars above each year. Clean energy and technologies include solar, wind, bioenergy, nuclear, fuel cells, hydrogen, $CO_2$ capture and storage, other power and storage, and energy efficiency.

SOURCE: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 March 2011.

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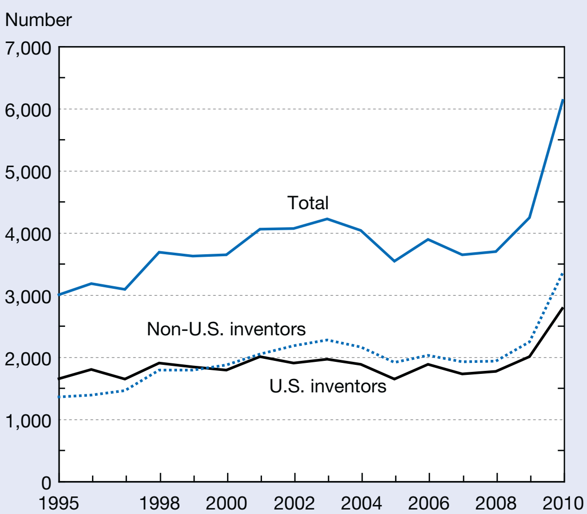
were granted about 45% of the 6,100 clean energy and pollution control technology patents in 2010, continuing the advantage of non-U.S. inventors in these fields since 2000.[38] The decline in the U.S. share of U.S. patent awards since 2000 suggests increased foreign technological capabilities in this area.

Among non-U.S. inventors, Japan, the EU, and South Korea, in that order, are the main recipients of U.S. patents for clean energy and pollution control technologies, with a collective share of 84% of patents granted to all non U.S. inventors (figure 6-64 and appendix table 6-66). Japan received 43% (down from more than 50% in the early 2000s); EU inventors received 30% (down from 36% in 2000). South Korean inventors received 12% of these non-U.S. inventor patents, up steeply from 3% in 2000. No other country has a substantial share of U.S. patents in this area.

Clean energy and pollution control technology patents comprise four broad areas: alternative energy with 3,000 patents granted, energy storage with 1,000 patents, smart grid with 500 patents, and pollution mitigation with 1,900 patents (table 6-13 and appendix tables 6-67, 6-68, 6-69, and 6-70). The proportion of clean energy patents rose from 26% in 1995 to 49% in 2010, with major share gains by fuel cell and losses by nuclear patents (appendix tables 6-71 and 6-72). Energy storage patents advanced from 8% to 16%, and pollution mitigation technologies declined from 58% to 31%, driven by share losses of air quality, water quality, and recycling (appendix tables 6-73, 6-74, and 6-75).

Figure 6-63
**USPTO patents in clean energy and pollution control technologies, by U.S. and non-U.S. inventors: 1995–2010**




USPTO = U.S. Patent and Trademark Office

NOTES: Clean energy and pollution control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, hydropower, wave/tidal/ocean, geothermal, and electric/hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies classified by The Patent Board™. Patent grants fractionally allocated among regions/countries on basis of proportion of residences of all named inventors.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2011). See appendix table 6-66.

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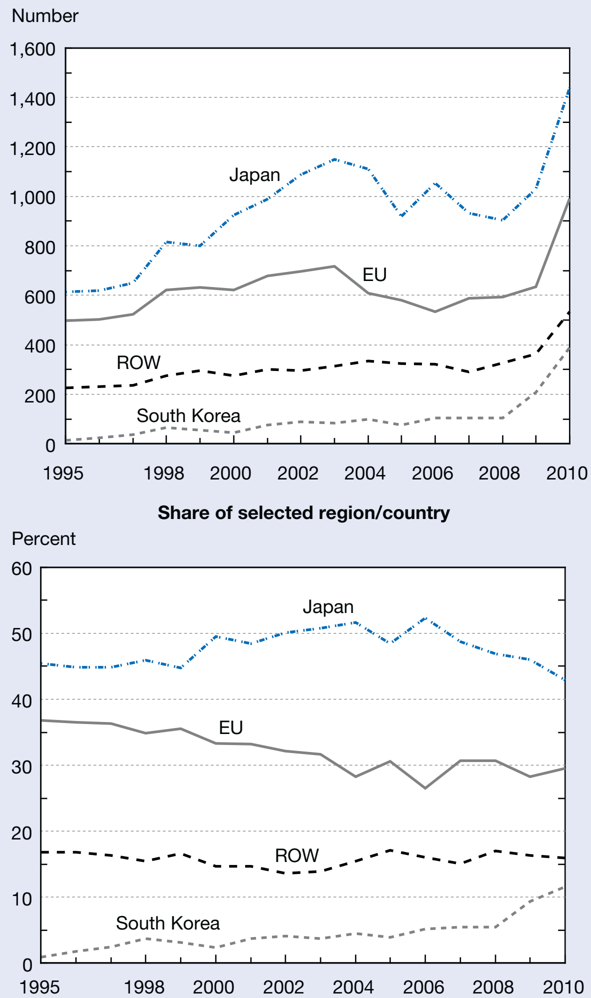
Figure 6-64
**USPTO patents granted to non-U.S. inventors in clean energy and pollution control technologies, by selected region/country: 1995–2010**




EU = European Union; ROW = rest of world; USPTO = U.S. Patent and Trademark Office

NOTES: Clean energy and pollution control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, hydropower, wave/tidal/ocean, geothermal, and electric/hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies classified by The Patent Board™. Patent grants fractionally allocated among regions/countries on basis of proportion of residences of all named inventors. EU includes current member countries.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2011). See appendix table 6-66.

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Table 6-13
**USPTO patents granted in clean energy and pollution control technologies, by selected area: Selected years, 1995–2010**

| Technology area | 1995 | 2000 | 2005 | 2008 | 2010 |
|---|---|---|---|---|---|
| All clean energy and pollution control technologies | 2,991 | 3,641 | 3,533 | 3,688 | 6,145 |
| Alternative energy | 825 | 1,154 | 1,482 | 1,606 | 2,993 |
| Bioenergy | 43 | 71 | 60 | 100 | 222 |
| Electric and hybrid vehicles | 129 | 247 | 365 | 377 | 532 |
| Fuel cells | 104 | 219 | 518 | 534 | 1,031 |
| Geothermal | 23 | 21 | 19 | 29 | 41 |
| Hydropower | 24 | 32 | 30 | 43 | 72 |
| Nuclear | 263 | 144 | 127 | 83 | 120 |
| Solar | 210 | 377 | 244 | 238 | 651 |
| Wind | 28 | 55 | 137 | 197 | 355 |
| Energy storage | 227 | 476 | 461 | 526 | 980 |
| Batteries | 124 | 285 | 224 | 235 | 547 |
| Hydrogen production and storage | 54 | 114 | 161 | 193 | 278 |
| Ultracapacitors | 24 | 52 | 61 | 83 | 131 |
| All others | 28 | 37 | 34 | 27 | 41 |
| Smart grid | 295 | 277 | 288 | 385 | 528 |
| Pollution mitigation | 1,717 | 1,864 | 1,456 | 1,321 | 1,887 |
| Air | 701 | 835 | 819 | 719 | 1,076 |
| Capture and storage of carbon and other greenhouse gases | 41 | 71 | 72 | 74 | 152 |
| Cleaner coal | 64 | 72 | 60 | 54 | 158 |
| Environmental remediation | 160 | 140 | 76 | 78 | 89 |
| Recycling | 327 | 322 | 170 | 120 | 186 |
| Solid waste | 304 | 235 | 137 | 116 | 129 |
| Water | 301 | 385 | 274 | 281 | 319 |

USPTO = U.S. Patent and Trademark Office

NOTES: Clean energy and pollution control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, bioenergy, hydropower, wave/tidal/ocean, geothermal, and electric/hybrid. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gasses. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Technologies classified by The Patent Board™. Sum of individual technologies may exceed broad areas and sum of broad categories may exceed total because some patents are assigned to multiple individual technologies or broad areas.

SOURCE: The Patent Board™, special tabulations (2011) of Proprietary Patent database. See appendix tables 6-66–6-84.

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Patent technology activity indexes measure the world share of a region, country, or economy in clean energy and clean technologies relative to its world share in patents in all technologies. A ratio greater than 1 signifies that patents by a region/country/economy are concentrated in a particular technology (table 6-14).

In clean energy patents, the U.S. has a high concentration in bioenergy and solar technologies and relatively low patent activity in fuel cells, hybrid vehicles, and wind energy (table 6-14 and appendix tables 6-45, 6-71, 6-76, 6-77, 6-78, and 6-79). The EU has relatively high concentrations in bioenergy, wind, and nuclear and relatively low concentration in electric hybrid technologies (appendix table 6-72). Japan has a high concentration of patents in electric hybrid technologies and fuel calls, but relatively low activity in bioenergy, nuclear, and solar. South Korea's concentration of patent activity is low across the range of clean energy.

The United States and EU have relatively low concentrations of patents in energy storage because of their low activity in battery technology, but this is an area of high concentration for Japan and South Korea (table 6-14 and appendix tables 6-45, 6-68, and 6-80). Despite its overall low concentration of patents in energy storage, the United States has a high concentration of patents in hydrogen power and storage (appendix table 6-81).

In smart grid, the United States has a high concentration of patents, the EU has a slightly above average concentration and Japan and South Korea have relatively low concentrations (appendix tables 6-45 and 6-69).

In pollution mitigation technologies, the United States has a slightly above average concentration of patents, with very high concentration in clean coal and slightly higher concentration in carbon capture and storage (table 6-14 and appendix tables 6-45, 6-82, and 6-83). The EU has a particularly high concentration of patents in air pollution, carbon capture and storage, and solid waste (appendix tables 6-73 and 6-84). Japan has a relatively low concentration in this area, with the exception of air pollution. South Korea has relatively low concentrations in all pollution mitigation technologies.

Table 6-14
**Patenting activity in selected clean energy and pollution control technologies, by selected region/country: 2007–10**
(Activity index)

| Technology | United States | EU | Japan | South Korea |
|---|---|---|---|---|
| All clean energy and pollution control technologies | 0.95 | 1.14 | 1.16 | 0.94 |
| Alternative energy | 0.92 | 1.24 | 1.22 | 0.87 |
| Bioenergy | 1.32 | 1.26 | 0.23 | 0.11 |
| Fuel cells | 0.79 | 0.92 | 1.65 | 1.46 |
| Hybrid electric | 0.76 | 0.89 | 2.02 | 0.78 |
| Nuclear | 0.96 | 1.94 | 0.79 | 1.26 |
| Solar | 1.13 | 1.01 | 0.80 | 0.50 |
| Wind | 0.86 | 2.92 | 0.31 | 0.19 |
| Energy storage | 0.73 | 0.54 | 1.71 | 2.58 |
| Batteries | 0.42 | 0.35 | 2.09 | 4.74 |
| Hydrogen power and storage | 1.16 | 0.86 | 0.95 | 0.62 |
| Smart grid | 1.23 | 1.02 | 0.50 | 0.48 |
| Pollution mitigation | 1.03 | 1.33 | 0.96 | 0.40 |
| Air | 0.92 | 1.50 | 1.30 | 0.38 |
| Capture and storage of carbon and other greenhouse gases | 1.18 | 1.55 | 0.48 | 0.36 |
| Cleaner coal | 1.43 | 0.89 | 0.34 | 0.33 |
| Solid waste | 1.10 | 1.39 | 0.41 | 0.56 |
| Water | 1.20 | 0.98 | 0.53 | 0.56 |

EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Clean energy and pollution control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, bioenergy, hydropower, wave/tidal/ocean, geothermal, and electric/hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies classified by The Patent Board™. Patent grants fractionally allocated among regions/countries on basis of proportion of residences of all named inventors. EU includes current member countries. Activity index consists of ratio of region/country's share of indicated technology to region/country's share of total grants. A ratio of greater than one signifies more active patenting in the selected technology; a ratio of less than one signifies less active patenting.

SOURCE: The Patent Board™, special tabulations (2011) of Proprietary Patent database. See appendix tables 6-66–6-84.

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## Conclusion

The U.S. economy continues to be the leading global economy in technology-based industries as measured by its overall performance, market position in KTI industries, and position in patenting and other measures of innovation-related activities.

The strong competitive position of the U.S. economy is tied to continued U.S. global leadership in many KTI industries. The United States continues to hold the dominant market position in commercial KI service industries, which account for nearly one-fifth of global economic activity. The U.S. trading position in technology-oriented services remains strong, as evidenced by the continued U.S. surplus in commercial KI services and licensing of patents and trade secrets. The United States is the leading source of RD&D and venture capital financing of clean energy and technologies.

The overall U.S. ranking notwithstanding, its market position in most of these industries has either flattened or slipped. Productivity growth of the U.S. economy has slowed in the 2000s relative to the 1990s. The historically strong U.S. trade position in advanced technology products has shifted to deficit because of the faster growth of imports than exports. This shift is due in part to U.S. companies moving assembly and other activities to China, other East Asian countries, and elsewhere. However, the U.S. deficit also reflects the development of indigenous capability by China and other East Asian countries in HT manufacturing industries.

China and other emerging Asian economies are showing rapid progress in their overall economic growth and technological capabilities. Productivity growth has accelerated, coinciding with an increase in the concentration of KTI industries in many of their economies. Their market positions in KTI industries—particularly HT manufacturing industries—have strengthened, and their shares of U.S. and economically valuable patents have risen, led by South Korea and Taiwan. The number of Chinese patents has soared, with Chinese and non-Chinese inventors each having a 50% share, suggesting the expansion of technological activity by domestic and foreign companies in China's rapidly growing economy.

Among individual large countries, China's progress clearly stands out. China has become a leading global producer and exporter of HT manufacturing goods. It has become a major global assembly center, supplied by components and inputs from East Asian economies. However, China's rapid progress in other indicators of technological capability and the nascent rise of globally competitive Chinese companies suggest that China is moving to more technologically challenging and higher end manufacturing activities. China has become the world's largest source of commercial financing for clean energy and is home to rapidly growing wind and solar industries.

The EU's position has been similar to that of the United States for much of the 2000s—relatively strong overall economic performance with a slowdown in productivity and flat or slight declines in its market position in KTI industries. However, the EU has suffered more severe losses in its market position in KTI industries than the United States during the worldwide recession in part because of the EU's debt and fiscal problems. Japan's economy has shown less dynamism compared with the United States and the EU, and its market position has declined steeply in many KTI industries. Japan's loss of market position in HT manufacturing industries is due, in part, to Japanese companies shifting production to China and other Asian economies.

The global recession had a disproportionately severe impact on the United States, the EU, and other developed economies, with production of their technology-intensive industries declining in 2009. In contrast, technology-intensive industries of developing economies, led by China, continued to grow during the global recession and increased their market positions relative to developed economies. Worldwide output of technology-intensive industries recovered in 2010, with much faster growth by China and other developing economies. Recovery of technology-intensive industries in the developed economies in 2010 was more evident in the United States and Japan than in the EU. Whether the global downturn will lead to fundamental changes in the market positions of the United States and other developed economies in the production and trade of KTI industries remains uncertain.

## Notes

1. See Mudambi (2008) and Reynolds (2010) for a discussion on the shift to knowledge-based production and geographical dispersion of economic activity.

2. See OECD (2001) for a discussion of classifying economic activities according to degree of "knowledge intensity." Part of the discussion on trade uses a different, product-based classification of the U.S. Census Bureau under the terminology *advanced technology products.*

3. Like all classification schemes, the OECD classification has shortcomings. For example, KTI industries produce some goods or services that are neither knowledge intensive nor technologically advanced. In addition, multiproduct companies that produce a mix of goods and services, only some of which are KTI, are assigned to their largest business segment. Nevertheless, data based on the OECD classification allow researchers and analysts to trace, in broad outline, the worldwide trends towards greater interdependence in science and technology and the development of KTI sectors in many of the world's economies.

4. In designating these HT manufacturing industries, OECD took into account both the R&D expenditures made directly by firms and R&D embedded in purchased inputs (indirect R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct R&D intensities were calculated as the ratio of total R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated using the technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several nonmanufacturing industries have R&D intensities equal to or greater than those of industries designated by the OECD as HT manufacturing. For additional perspectives on OECD's methodology, see Godin (2004).

5. See Atkinson and McKay (2007: 16–17) for a discussion of and references to the impact of IT on economic growth and productivity.

6. The sum of the value added attributable to individual commercial KI services does not add to the total because of rounding.

7. Data on the health sector includes social services.

8 See Bresnahan and Trajtenberg (1995) and DeLong and Summers (2001) for a discussion of ICT and general-purpose technologies.

9. These ICT infrastructure indexes originate from the Connectivity Scorecard, which has developed a variety of ICT indexes for developed and developing countries. The ICT infrastructure indexes are benchmarked against the best-in-class country in developed and developing countries. The business ICT infrastructure index is composed of metrics on business hardware and software and penetration of business lines. The consumer infrastructure index is composed of indicators on penetration of telephone line and broadband. The government infrastructure index is composed of metrics related to e-government capacity and the share of schools connected to the Internet. More information on the methodology can be found at http://www.connectivityscorecard.org/methodology/

10. See Williamson and Raman (2011) for a discussion of China's acquisition of foreign companies.

11. Commercial KTI services and goods trade does not correspond to commercial KTI industries because industry and trade data are collected on different bases. Industry production data are classified by primary industry and trade data are classified by product or service.

12. Data on commercial KI trade between China and Hong Kong are not available.

13. The sums of the categories do not add to the total, which also includes a small amount of trade in noncommercial KI services, including construction services.

14. IHS Global Insight data as of July 2009.

15. The U.S. trade balance is affected by many other factors, including currency fluctuations, differing fiscal and monetary policies, and export subsidies between the United States and its trading partners.

16. China is the single largest trading partner for the United States in goods trade according to recent data from the U.S. Census. For more information, see http://www.census.gov/foreign-trade/index.html.

17. The discrepancy in the trade figures is because of rounding.

18. U.S. multinational financial services data for 1999 and 2006 do not include banks and depository institutions, which are included in the global industry data on financial services.

19. U.S. direct investment abroad by industry and country is a lower bound estimate because an increasing share of U.S. direct investment (36% in 2008) is through holding companies that invest in other industries that may be in a different country. For more information, see Ibarra and Koncz (2008).

20. OECD (2005).

21. Definitions of innovation differ widely, but a common element is the commercialization of something that did not previously exist.

22. The NSF BRDIS survey's definition of innovation is very similar to the OECD definition. For more information, see NSF, Business R&D and Innovation Survey, http://www.nsf.gov/statistics/srvyindustry/about/brdis/.

23. BRDIS data are not available for the entire U.S. service sector.

24. Rather than granting property rights to the inventor, as is the practice in the United States and many other countries, some countries grant property rights to the applicant, which may be a corporation or other organization.

25. U.S. patent law states that any person who "invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent." The law defines *nonobvious* as "sufficiently different from what has been used or described before that it may be said to be nonobvious to a person having ordinary skill in the area of technology related to the invention." These terms are part of the criteria in U.S. patent law. For more information, see USPTO, "What Is a Patent?" Available at http://www.uspto.gov/web/offices/pac/doc/general/index.html#patent. Accessed 19 June 2009.

26. The Japan Patent Office is also a major patent office but has a much smaller share of foreign patents than the USPTO and the European Patent Office.

27. Although the USPTO grants several types of patents, this discussion is limited to utility patents, commonly known as patents for inventions. They include any new, useful, or improved-on method, process, machine, device, manufactured item, or chemical compound.

28. Unless otherwise noted, USPTO assigns patents to countries on the basis of the residence of the first-named inventor.

29. Triadic patent families with co-inventors residing in different countries are assigned to their respective countries/economies on a fractional-count basis (i.e., each country/economy receives fractional credit on the basis of the proportion of its inventors listed on the patent). Patents are listed by priority year, which is the year of the first patent filing. Data for 1998–2003 are estimated by the OECD.

30. The high-technology definition used here is from the Bureau of Labor Statistics and differs from that used in earlier sections. See Hecker (2005) for a definition and the methodology for determining HT industries.

31. According to U.S. Census data, the number of U.S. microbusinesses in non-HT industries in 2008 was 3.3 million, with 2.7 million operating in service industries.

32. Another possibility is that venture capital investor behavior changed because fewer opportunities for attractive risky investments were available in the 2000s than in the 1990s.

33. The IEA manual states: "The IEA concept of Energy RD&D differs from the Frascati concept of R&D, in that (i) it focuses on energy related programmes only; (ii) it includes "demonstration projects"; and (iii) it includes state owned companies. …The energy RD&D data collected by the IEA should not be confused with the data on government budget appropriations or outlays on R&D (GBAORD) collected by the OECD Directorate for Science, Technology, and Industry for the socio-economic objective 'Production, distribution and rational utilisation of energy'…" See IEA (2011), http://www.iea.org/stats/RDD%20Manual.pdf, pp. 16–17.

34. Bloomberg's data include investment in renewable energy, biofuels, energy efficiency, smart grid and other energy technologies, carbon capture and storage and infrastructure investments targeted purely at integrating clean energy. Investment in solar hot water, combined heat and power, renewable heat, and nuclear are excluded, as are the proceeds of mergers and acquisitions (which do not contribute to new investment).

35. See UNEP 2009, p. 18, for a discussion of the biofuels sector.

36. The IEA has no official definition of clean energy. This discussion includes public RD&D in energy efficiency, renewable energy, nuclear, hydrogen and fuel cells, $CO_2$ capture and storage, and other power and storage technologies.

37. The USPTO initiated a green technology pilot program on December 7, 2009, that expedites processing of some applications related to green technologies. For more information, see http://www.uspto.gov/patents/init_events/green_tech.jsp.

38. See note 28.

## Glossary

**Affiliate:** A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

**Angel investment:** Financing from affluent individuals for business startups, usually in exchange for ownership equity. Angel investors typically invest their own funds or organize themselves into networks or groups to share research and pool investment capital.

**Asia-8:** India, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Taiwan, and Thailand.

**Commercial knowledge-intensive services:** Knowledge-intensive services that are generally privately owned and compete in the marketplace without public support. These services are business, communications, and financial services.

**Company or firm:** A business entity that is either a single location with no subsidiary or branches or the topmost parent of a group of subsidiaries or branches.

**EU (European Union):** The 27 member states of the European Union since 2007 include Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

**Foreign direct investment:** Financial investment by which a person or an entity acquires a lasting interest in and a degree of influence over the management of a business enterprise in a foreign country.

**Gross domestic product (GDP):** The market value of all final goods and services produced within a country within a given period of time.

**High-technology manufacturing industries:** Those that spend a relatively high proportion of their revenue on R&D, consisting of aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

**Information and communications technology industries:** A subset of knowledge- and technology-intensive industries, consisting of two high-technology manufacturing industries, computers and office machinery and communications equipment and semiconductors, and two knowledge-intensive service industries, communications and computer services, which is a subset of business services.

**Intellectual property:** Intangible property resulting from creativity that is protected in the form of patents, copyrights, trademarks, and trade secrets.

**Intra-EU exports:** Exports from EU countries to other EU countries.

**Knowledge-intensive industries:** Those that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, communications, education, financial, and health services.

**Knowledge- and technology-intensive industries:** Those that have a particularly strong link to science and technology. These industries are five service industries, financial, business, communications, education, and health, and five manufacturing industries, aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

**Normalizing:** To adjust to a norm or standard.

**Not obvious:** One criterion (along with "new" and "useful") by which an invention is judged to determine its patentability.

**Productivity:** The efficiency with which resources are employed within an economy or industry, measured as labor or multifactor productivity. Labor productivity is measured by GDP or output per unit of labor. Multifactor productivity is measured by GDP or output per combined unit of labor and capital.

**Purchasing power parity (PPP):** The exchange rate required to purchase an equivalent market basket of goods.

**R&D intensity:** The proportion of R&D expenditures to the number of technical people employed (e.g., scientists, engineers, and technicians) or the value of revenues.

**Triadic patent:** A patent for which patent protection has been applied within the three major world markets: the United States, Europe, and Japan.

**Utility patent:** A type of patent issued by the U.S. Patent and Trademark office for inventions, including new and useful processes, machines, manufactured goods, or composition of matter.

**Value added:** A measure of industry production that is the amount contributed by the country, firm, or other entity to the value of the good or service. It excludes the country, industry, firm, or other entity's purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

**Value chain:** A chain of activities to produce goods and services that may extend across firms or countries. These activities include design, production, marketing and sales, logistics, and maintenance.

**Venture capitalist:** Venture capitalists manage the pooled investments of others (typically wealthy investors, investment banks, and other financial institutions) in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always participate in managerial decisions.

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